ADDIS ABABA UNIVERSITY

FACULTY OF VETERINARY MEDICINE

CATTLE TICK DYNAMICS IN DIFFERENT AGRO-ECOLOGICAL ZONES OF WOLAYTA, SOUTHERN ETHIOPIA

BY

DESIE SHEFERAW MEREBA

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A thesis submitted to the Faculty of Veterinary Medicine, Addis Ababa University in partial fulfilment of the requirements for the Degree of Master of Science in Tropical Veterinary Epidemiology

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TABLE OF CONTENTS **PAGE**

LIST OF TABLES **PAGE**

LIST OF FIGURES **PAGE**

LIST OF ANNEXES **PAGE**

LIST OF ABBREVIATION

AC	*Amblyomma cohaerens*
AG	*Amblyomma Gemma*
AL	*Amblyomma lepidum*
AV	*Amblyomma variegatum*
BD	*Boophilus decoloratus*
CI	Confidence interval
CSA	Central Statistical Authority
^0C	Degree Celsius
FAO	Food Agriculture Organization
GDP	Grand domestic product
GPS	Geographical positioning system
HyM	*Hyalomma marginatum rufipes*
ILRI	International Livestock Research Institute
mm	millimetre
NMSA	National Meteorological Service Agency
RhE	*Rhipicephalus evertsi evertsi*
RhG	*Rhipicephalus guilhoni*
RhM	*Rhipicephalus muhsamae*
RhPrt	*Rhipicephalus praetextatus*
SNNPRS	Southern Nation Nationalities People Regional State
TBD	Tick borne disease
α	Greek letter alpha
η	Greek letter eta

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ABSTRACT

A study on cattle tick dynamics was conducted on three agro-ecological zones of Wolayta, Ethiopia, from August 2004 to March 2005 with the objective of identifying the common species, and determining the tick burden difference of indigenous and Holstein cross. The study was conducted using cross-sectional and longitudinal designs to asses the adult ticks attached on cattle during wet and dry periods; and asses the monthly total tick burden on animals in all the three agro-ecological zones respectively. A total of 6191 and 5991 adult ticks were collected from half-body regions of 138 cattle from each agro-ecological zone in wet and dry periods. From these four genera, and eleven species in general identified in all the study areas. The percentages of tick genera identified at highland, midland and lowland in wet and dry periods were *Amblyomma* (46.44% and 25.11%; 45.87% and 50.47%; 58.94% and 48.93% respectively), *Boophilus* (46.92% and 73.34%; 47.53% and 47.47%; 30.71% and 45.40% respectively), *Rhipicephalus* (5.08% and 1.55%; 6.60% and 2.06%; 8.41% and 5.67% respectively) and *Hyalomma* (1.56% and 1.94% at highland and lowland respectively in wet period only). During the wet period *Boophilus decoloratus* (46.92%), *Amblyomma variegatum* (20.82%), *Amblyomma gemma* (12.02%), *Amblyomma cohaerens* (10.26%), *Amblyomma lepidum* (3.32%) and *Rhipicephalus evertsi evertsi* (2.15%) were found to be the six most top common tick species at highland in decreasing order of abundance. While *Boophilus decoloratus* (47.53%), *Amblyomma variegatum* (25.95%), *Amblyomma gemma* (13.63%), *Amblyomma cohaerens* (4.02%), *Rhipicephalus evertsi evertsi* (4.37%) and *Amblyomma lepidum*

(2.27%) were found to be the six most abundant and common tick species at Kokatie, midland, in descending order. *Amblyomma variegatum* (36.75%), *Boophilus decoloratus* (30.71%), *Amblyomma gemma* (17.78%), *Rhipicephalus evertsi evertsi* (6.14%), *Amblyomma cohaerens* (2.58%), and *Amblyomma lepidum* (1.83%) were found to be the six most top common tick species at Bombie, lowland, in decreasing order of abundance. During dry period *Boophilus decoloratus* (73.35%), *Amblyomma gemma* (17.87%), *Amblyomma variegatum* (4.20%), *Amblyomma cohaerens* (2.16%) and *Rhipicephalus evertsi evertsi* (1.30%) at highland; *Boophilus decoloratus* (47.47%), *Amblyomma gemma* (29.03%), *Amblyomma variegatum* (10.11%), *Amblyomma cohaerens* (5.99%), and *Amblyomma lepidum* (5.34%) at midland; and *Boophilus decoloratus* (45.40%), *Amblyomma gemma* (35.12%), *Amblyomma variegatum* (11.39%), *Rhipicephalus evertsi evertsi* (3.49%) and *Amblyomma lepidum* (2.19%) at lowland were found to be the most top tick species at each sites in decreasing order of abundance.

From this study the relative number of *Amblyomma variegatum* was significantly higher during wet period than dry period at all the three agro-ecological zones ($t = 10.2719$, $P = 0.000$ at $\alpha = 0.05$) . But the relative number of A*mblyomma gemma* was significantly highest in dry period ($t = -7.7583$, $P = 0.000$ at $\alpha = 0.05$). At all the study areas *Amblyomma cohaerens* relative distribution was higher significantly in wet ($t = 4.3619$, $P = 0.000$ at $\alpha = 0.05$). The relative number of *Boophilus decoloratus* was significantly higher during dry period ($t = -5.3937$, $P = 0.0000$ at $\alpha = 0.05$). The sex ratios of all tick species identified during this study periods, both wet and dry, were skewed towards male except for *Boophilus decoloratus*. The most preferred predilection sites of al

Amblyomma species were scrotum/udder, brisket, inside part of legs and belly in decreasing order of preference. *Boophilus decoloratus* preferred attachment sites were dewlap, belly, legs and head. Rhipicephalus species primarily attached to anogenital regions, but few on ear area. Significantly higher total tick burden or infestation was found in wet months (August, September and October), and then start to decline till February ($F= 185.843$, $P= 0.000$ at $\alpha= 0.05$). Among the two breeds, indigenous and Holstein cross, it was found that Holstein cross was infested by high total tick populations ($F= 370.610$, $P= 0.000$ at $\alpha= 0.05$).

Based on the finding of this study it can be concluded that among the species of ticks identified *Amblyomma variegatum*, *Amblyomma cohaerens*, *Amblyomma gemma*, *Boophilus decoloratus* and *Rhipicephalus evertsi evertsi* were very important. The total tick burden observed in wet period both on indigenous and Holstein cross; in all the study periods on Holstein cross were higher comparatively.

Key words: Agro-ecological zone, Dynamics, Total tick, Half-body regions, indigenous, Sex ratio, Attachment sites, Highland, Midland, Lowland

1. INTRODUCTION AND OBJECTIVES

1.1 Introduction

Ethiopia, located in the horn of Africa between latitude from 3º N to 15º N of the equator and longitude from 33º E to 48º E (CSA, 2003 and Tamire, 2003), is an agrarian country with an estimated human population of about 62.9 million and a total land area of 1,101,000 km^2 (Tamire, 2003). The proportion of total population in agricultural sector is 82.4% (CSA, 2003). According to CSA (2003) and FAO.AGAL (2003) estimate the livestock population of Ethiopia is about 30 million heads of cattle, 24 million sheep, 18 million goats, 7.2 million equines, one million camels, 25 thousands pigs and 55.6 million poultry. Livestock are an important and integral part of farming systems in Ethiopia. Apart from being a source of high quality protein (meat, milk and eggs), they contribute to the economic welfare of the people by providing hides, skins, power and traction for agricultural purposes, fertilizer for increasing the productivity of smallholdings (Minjauw and McLeod, 2003 and Torr *et al*., 2003). They are also a "living saving bank" and serve as a financial reserve for periods of economic distress and crop failure as well as a primary source of cash income (Jajasuriya, 1999; ILRI, 1999 and Minjauw and McLeod, 2003). But most importantly, they are the means of converting poor quality forages from marginal land, surplus crops, crop residues and by-products of agriculture and industry to high value commodities such as meat and milk, which increase income and hence enhance the economic viability of the farming system (Jajasuriya, 1999). The Ethiopian livestock contribute about 18.8% of the total GDP (FAO.AGAL, 2003). Among livestock, cattle are a primary resource for the people and government of Ethiopia (ILRI, 1999).

According to Walker *et al*. (2003) ticks that are considered to be most important to the health of domestic animals in Africa comprise about forty species. Among these the most important tick species in Ethiopian cattle are *Amblyomma gemma*, *Amblyomma variegatum, Amblyomma cohaerens, Amblyomma lepidum* (Morel, 1980; Pegram *et al*.,1981; de Castro, 1994 and Mekonnen *et al*., 2001), *Boophilus decoloratus,* (Pegram *et al*., 1981; Haile, 1987; Mekonnen, 1988; de Castro, 1994 and Walker *et al*., 2003), *Boophilus annulatus* (Haile, 1987; de Castro, 1994) *Rhipicephalus pulchellus, Rhipicephalus pravus, Rhipicephalus evertsi evertsi, Rhipicephalus praetextatus, Rhipicephalus bergeoni* (Yilma *et al*., 1995; Bekele, 1996; Mekonnen *et al*., 2001), *Rhipicephalus muhasmae* (de Castro, 1994; Solomon and Kaaya, 1996; Mekonnen *et al*., 2001; Regassa, 2001 and Walker *et al*., 2003), *Rhipicephalus lunulatus* (Morel, 1980; Pegram *et al*., 1981), *Rhipicephalus simus* (Pegram *et al*., 1981; Mekonnen *et al*., 2001 and Walker *et al*., 2003), *Hyalomma dromedarii, Hyalomma trucatum, Hyalomma marginatum rufipes, Hyalomma excavatum, Hyalomma impelatum* (Pegram *et al*., 1981; Yilma *et al*., 1995; Bekele, 1996 and Walker *et al*., 2003), *Haemaphysalis aciculifer and Haemaphysalis parmata* (Pegram *et al*., 1981; Mekonnen, 1988 and de Castro, 1994). The country's environmental condition and vegetation are highly conducive for ticks and TBD perpetuation (Pegram *et al*., 1981).

Wolayta Zone is located between latitude 6º4' N and 7º1' N and, longitude 37º4'E and 38º2' E, in the SNNPRS. In the area there are about 658,886 heads of cattle, both local and crossbreed (CSA, 2003; Wolayta Zone Agricultural Department, 2003 and Wolayta Zone Finance and Economic Development Department, 2003). They are always under the risk of tick infestation and TBD challenge. The important tick species found in Wolayta include: *Amblyomma variegatum, Amblyomma cohaerens, Amblyomma gemma, Amblyomma lepidum, Boophilus decoloratus, Rhipicephalus evertsi evertsi, Rhipicephalus pulchellus, Rhipicephalus simus, Rhipicephalus bergeoni, Rhipicephalus pravus and Hyalomma marginatum rufipes* (Naser, 1985 and G/Michael, 1993).

Therefore, the aim of this study is to build up base-line data on tick population dynamics in selected agro-ecological zones to add up into the existing knowledge of tick distribution and abundance in relation to altitude, season, and other correlates. The knowledge of tick population dynamics enables to design control strategies suit to the different types of livestock production system in different environment; to calculate the losses in productivity caused by ticks and the economic benefits of control programs of different intensity.

1.2 Objectives

The major objectives of this study include:

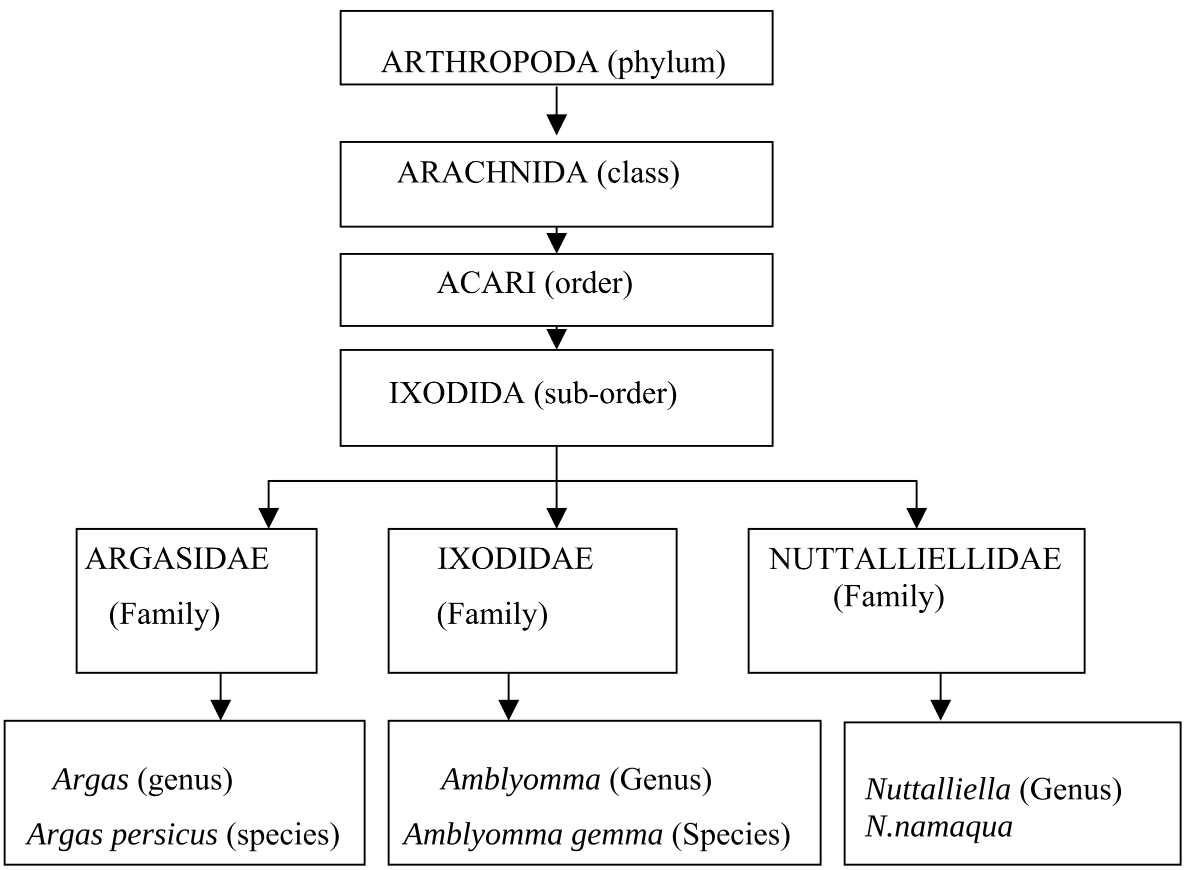
- To identify the common cattle tick species prevalent in different agro-ecological zones of Wolayta and to establish their quantitative and qualitative hierarchy.
- To observe cattle tick dynamics in different agro-ecological zones, and in different periods.
- To assess cattle breed difference with regard to tick burden.

2. LITERATURE REVIEW

2.1. Ticks

Ticks are closely related to animals such as insects and spiders, which are all without a spine. They belong to the groups called the phylum Arthropoda, the class Arachnida and order Acari (Hendrix, 1998; Walker *et al*., 2003; and Latif and Walker, 2004). Since they belong to the acarines, any infestation of domestic animals by ticks is referred as acariasis (Hendrix, 1998).

According to FAO (1984) ticks are classified as follows:



Family Argasidae are soft ticks. It has one important genus that infests cattle, *Ornithodoros* (Latif and Walker, 2004). Argasidae are wandering ticks, which only remain on their host while feeding. Ixodidae are hard ticks. They are disease vectors, which are most important for animal production in the tropics. The following genera belong to this family: *Boophilus*, *Amblyomma*, *Hyalomma*, *Rhipicephalus*, *Haemaphysalis*, *Dermacentor*, *Ixodes* and *Margaropus* (Kettle, 1995). These are genera of hard tick that popularly feed on cattle (Kettle, 1995). Both families have in common the development form the egg to the six-legged larva, to the eight-legged nymph and then after renewed moulting, to the imago. In order to locate the host, both families of ticks possess a number of chemoreceptor, Haller`s organ, which is located on the tarsus of the first pair of legs (Kettle, 1995 and Walker *et al*., 2003).

The family Ixodidae, hard ticks, Characterized by the presence of a rigid chitinous scutum, which covers the entire dorsal surface of the adult male, in the adult female, and in the larva and nymph, it extends for only a small area, which permits the abdomen to swell after feeding (Kettle, 1995). The monotypic family Nuttalliellidae contain the species *Nuttalliella namaqua* (Hopla *et al*., 1994).

Ticks have lost all of the external signs of body segmentation and are divided into two body components (Hendrix, 1998) that is the gnathostoma or capitulum, the mouthparts or a fusion of head and thorax, and the idiosoma (Kaufmann, 1989; Wall and Shearer, 1997).

2.2. Biology of life cycle

An important feature of the biology of ticks is their high potential reproductive rate (Torr *et al*., 2003). They are dioecious, separate sex, and posses' tremendous reproductive capacity (Latif and Walker, 2004), and reproduce sexually, both Argasidae and Ixodidae (Bay and Harris, 1988). Since Ixodidae contains almost all the species of ticks of veterinary importance in cattle (Wall and Shearer, 1997) its life cycle is described as follows.

There are four stages in the life cycle of Ixodidae ticks: the egg, the six -legged larva, the eight-legged nymph and adult (Katherine, 1976). The adult ixodid female tick on the host sucks up considerable amount of blood and copulates with the male while feeding (Katherine, 1976 and Morel, 1989). According to Walker *et al*. (2003), and Latif and Walker (2004) observations in hard ticks mating takes place on the host, except for *Ixodes* where it may also occur when the ticks are still on the vegetation. After attachment to the host the female is inseminated once, before it is ready to fully engorge with blood, and subsequently completes its single large blood meal, but the males feed intermittently and mate with females repeatedly (Latif and Walker *et al*., 2004). During mating the male crawls under the female and after manipulating the female genital opening with its mouthparts, transfers the spermatheca, a sac containing the spermatozoa, into the opening, presumably with aid of his front legs (Walker *et al*., 2003). When the females fully engorged they have enough sperm stored to fertilize all their eggs. Then detach from the host and averagely deposit up to 18,000 eggs/female in a single batch, which ranges from

1000-20,000 eggs/female (Morel, 1989 Walker *et al*., 2003 and Latif and Walker, 2004). This difference depends on the variation of the various researchers or investigators observation. The oviposition occurs after a period of digestion and oogenesis in natural shelter, under protective cover of grasses, stone, in plant litter, etc. After a single oviposition the emptied females die (Walker *et al*., 2003). Under suitable conditions (mostly hot and humid), the egg hatches and six-legged larva emerges (Morel, 1989). After a period of maturation, it begins to seek the first host, either lying in wait on a grass blade, or moving to hunt actively. But the latter depends on the ambient temperature and humidity. Once the host is found taking of the blood meal lasts for 3-12 days or more, depending on the species and ambient conditions. Then the larvae moult to nymphs, which is eight-legged. Passing through a period of maturation or hardening by feeding the larvae moults to eight-legged nymph and sexually differentiated adult ticks developed form this nymphs (Morel, 1989 and Walker et al., 2003).

Generally there are three active stages in the life cycle of a hard tick: larva, nymph and adult tick (Jongejan and Uilenberg, 1994). Based on the number of hosts required to complete the development during their life cycle ticks can be classified as one-host, two-host and three-host (Walker *et al*., 2003 and Latif and Walker, 2004). Diagrammatic illustration of the life cycle of the one, two and three host ticks are presented as annex 10.

One-host ticks: the larvae, which emerge from the eggs 3-4 weeks after deposition at the earliest, attach themselves to a host animal where they complete their entire development.

On the host they develop from larvae to nymphs and imagos. Then copulate after maturation period and following engorgement female drops off and deposit eggs on the ground. Pictorial representation of one host tick life cycle is shown on Annex 10 plate 1. The entire development cycle takes mostly 19-21 days, but depending on the environmental condition (availability and level of humidity and temperature) can range from 15-40 days (Morel, 1980). All the species of Boophilus are the common examples of one host-tick (Walker, *et al*., 2003).

Two-host ticks: The eggs hatch to give larva, which can attaches to a host animal and feed on blood, then develops into nymph stage. After a maximum of 14 days, it drops off on to the ground where it reaches the imago stage in 20-30 days time. The adult looks for another host and feeds for 6-11 days, then female drops to the ground and deposit eggs, which will develop into larvae (Morel, 1980). Pictorial representation of two host ticks life cycle is shown on Annex 10 plate 2. Some examples of two-host ticks are: *Rhipicephalus bursa, Rhipicephalus evertsi evertsi, Hyalomma deteritum and Hyalomma marginatum turnicum* (Walker, *et al*., 2003).

Three-host ticks: The larvae merges from the eggs deposited on the ground, looks for a host, feed on it for 3-7 days, drops off and moults after 3-4 weeks on the ground. Then nymph climb to a second host in order to feed on it for 3-7days, leave it and moult into imago on the ground after 2-8 weeks. Then the adult ticks look for a third host to feed on, and for copulation with male, which takes 1-3 weeks. Finally, it drops off and completes the cycle with oviposition on the ground to continue another cycle (Latif and Walker, 2004). Pictorial representation of three host ticks shown on Annex 10 plate 3. All species of *Amblyomma, Dermacentor, Ixodes* and most species of *Hyalomma* (except few species) are three-host ticks (Okello-Onen, *et al*., 1999[a]).The entire development of one cycle may lasts up to one year since the different length of time spent in each stage on the ground (Latif and Walker, 2004).

2.3. Epidemiology of important cattle tick

Ticks occur in the temperate as well as in the tropical regions of the world. There are about 825 described species of tick in the world parasitizing domestic and wild animals as well as human (Walker *et al*., 2003). The most important situation to be considered in the epidemiology of ticks categorized into free-living developmental phase, host finding phase and parasitic phase. When ticks occur freely in the environment external factors like temperature and humidity are the major determinants of their development and growth (FAO, 1984).

Ticks habitat is composed of a variety of living and non-living things in the space in which it lives (Latif and Walker, 2004). They are adapted to two extremely contrasting components of their habitat: the physical environment and their host. When they are moulting and then questing in the physical environment they are in danger of drying out, starving and freezing, as well as exposed to predators (Walker *et al*., 2003; and Latif and Walker, 2004). The larvae are most susceptible because they have a high surface area relative to their small volume (Latif and Walker, 2004). Most ticks do not tolerate direct sunlight, dryness, or excessive rainfall. Their activity is restricted during cold period, but increases dramatically during hot and humid time (Hendrix, 1998). Moisture's complete absence is highly destructive (Katherine, 1976).

Ecology plays a central role in the control of ticks on livestock. Ecological information provides the basis for the control. Tick resistant cattle, pasture spelling and habitat modification are good examples of the manipulation of tick ecology for control purposes (FAO, 1984). The most important ecological factors influencing the occurrence of ticks in a biotope include temperature, which is a dynamic factor (organogenesis, activity), and relative humidity, which is a static factor, survival (Morel, 1989 and Latif and Walker, 2004). Even if the same factor affects the survival of all tick species to varying degrees, each species has its particular threshold temperature below that diapauses occurs in all in-stars. Obviously, field development periods will vary according to the temperature (FAO, 1984 and Morel, 1989).

The proportion of the development of a tick, which takes place each day, depends on the temperature of its surrounding. Progress of the rate of development is directly related to temperature (Katherine, 1976 and FAO, 1984). Egg and larval development, and egg production in engorged females are inhibited, while immature or unfed adults become quiescent (Morel, 1989). Relative humidity at microclimatic level is essential for the development and survival of eggs and larvae. The success of eggs in hatching depends primarily on the availability of adequate moisture, provided that temperatures are not too extreme for their development. Eggs are very sensitive to environmental condition, and the wide variation in the percentage of hatching is believed to largely determine the size of later tick population (FAO, 1984 and Morel, 1989). Each species is adapted to a particular relative humidity in a biotope and it varies with the instars and its size. Immatures have very specific requirements, whereas the adults can protect themselves better against evaporation because of their larger size and thicker tegument. Immature adapt their humidity requirement by developing in holes in the ground, cracks in rocks, litter, the base of vegetation layer, and other sheltered places (Morel, 1989). As compared to eggs engorged larvae and nymphs particularly are less susceptible to desiccation, and their success rates in moulting are usually high in the absence of extreme temperatures or dryness (FAO, 1984). But many species of ticks are able to survive for long periods without a blood meal. Nymphs usually live longer than larvae, and adults live longer than nymphs (Katherine, 1976).

According to Solomon and Kaaya (1998) observation at Abernossa ranch, Ethiopia, the engorgement periods were constant for both *Amblyomma* and *Boophilus*. But the pre-hatching and moulting periods were influenced by seasons. In addition, they found longest duration of the life cycle during the peak of rains and shortest during the dry humid season.

The second situation that has effect in the epidemiology of tick is the host finding phase. The success rate of unfed ticks in finding a host depends up on their longevity, responsiveness to hosts and the availability of hosts. The total proportion of a given tick population, which find a host, under continuous grazing, depends on the rate at which ticks are swept up by hosts and on their average survival time (FAO, 1984). The average survival time is determined by temperature and moisture availability (FAO, 1984 and Randolph, 1997). The available estimates for *Boophilus microplus* showed that the percentage of available larvae swept up by each week varied between 15 – 40% in trials in which stocking rates ranged from 1.5 – 5 beasts/hectare. In summer, these rates result in 40 – 100% of larvae finding a host during their lifetime (FAO, 1984).

The third important fundamental factor that governs the epidemiological pattern of ticks is the parasitic phase, which is the parasitic duration (FAO, 1984). One host ticks take about seventeen to twenty five days to complete engorgement. Larvae and nymphs of most three host ticks each complete engorgement in four to six days (FAO, 1984; Walker *et al.*, 2003; and Latif and Walker, 2004). But the larvae of two host ticks remain on the host where they moults to nymphs, feed to engorgement again and detach two to three after first attachment of the larvae (FAO, 1984 and Randolph, 1994). Much of the mortality of ticks during their life cycle occurs in the period of parasitic phase and is determined by the resistance of the host to tick feeding (FAO, 1984).

2.3.1. Host relationship

The survival of a population of ticks depends on the presence of maintenance hosts suitable for perpetuation, whenever ticks couldn't get host they will die of starvation. They are more limited in variety than the hosts on which larvae and nymphs of three-host ticks can survive; and more limited than those on which adult may attempt to feed but not necessarily survive (FAO, 1984 and Walker *et al*., 2003). They find their hosts in several ways. Some ticks live in open environments and crawl on to vegetation to wait for their hosts to pass by. This is a type of ambush and the behaviour of waiting on vegetation is known as questing. Ticks in the genera such as Rhipicephalus, Haemaphysalis and Ixodes, the larvae, nymph and adults quest on vegetation. Adult ticks of the genera Amblyomma and Hyalomma are active hunters; they run across the grounds to seek hosts that are near by. The general behaviour of seeking hosts in an open environment is described as exophilic (Walker *et al*., 2003).

It is observed that when cattle are less resistant due to nutritional stress, and lactation the tick survival rate increases (FAO, 1984 and Brown, 1985).

2.3.2. Host specificity

The degree of host specificity in Ixodid ticks vary from genera to genera or with in certain subgroups of various genera (Hoogstraal, 1956). Earlier ticks have characteristic species of hosts to which they are adapted. Hosts are usually in a group of similar species. For instance, all the *Rhipicephalus species* are adapted to feed on cattle, but some may survive by feeding on sheep or antelope (Walker *et al*., 2003). As sited by Tatchell (1987)

Hoogstraal and Aeschlimann defined different categories of tick-host specificity. The majority of ticks at least 700 of 850 ixodid species are characterized by more or less strict host specificity. Some have adapted either to a wide range of hosts (For example: *Ixodes ricinus*) while others have become host specific like *Boophilus species* (Tatchell, 1987). But now a day human and domesticated animal populations have recently intruded into long-established biotope possessing stable tick-host-parasite relationships. Hence ticks with originally strict or limited host specificity may thus be presented with a more-or-less acceptable alternative, which displaces the original host or is present in over whelming greater numbers (Tatchell, 1987). At present time, cattle constitute the only available hosts for ticks in an environment transformed by modern agricultural and livestock production system. But these ticks are not specific to cattle. They were originally associated with either local fauna, rodents and ungulates, which later replaced by cattle, partially or completely (Morel, 1989). It is known from Hoogstraal (1956) that *A. cohaerens* was east African buffalo tick. But now it is frequently reported that it attack cattle in areas where buffalo disappeared due to various reasons. The study conducted by de Castro (1994) in western zone of Ethiopia reinforces this view.

2.3.3. Attachment sites

Apart form its use in increasing the efficiency of control methods knowledge of the distribution of tick species on the host body nay facilitate sampling programme (Kaiser *et al*., 1982). Site specificity is one of the populations limiting System that operate through the restriction of tick species to certain parts of the host body. The host or aspects of the environment and ticks behaviour enforce it (Tatchell, 1987). The ticks grab on to the hosts using their front legs and then crawl over the skin to find a suitable place to attach and feed (Walker *et al*., 2003). They seek out places on the hosts where they are protected and have favourable conditions for their development and prefer to bite in to thin parts of the skin (Okello-Onen *et al.*, 1999[a]).

The host grooming response to the irritation level at tick attachment site may influence the distribution of ticks on the host body. With shorthaired hosts exposed to the full sun, insolation can prevent successful attachment and engorgement on the dorsum of the animal. Certain species have well-known adult tick predilection sites (Tatchell, 1987).

Depending on the type of ticks, site preference on the host depends on accessibility for attachment, to get blood and protection to overcome the environmental damage that inhibits their existence. Tick's location on the host is linked to the possibility of penetration by the hypostome. Species with a short hypostome for example, *Rhipicephalus species*, *Dermacentor species* and *Haemaphysalis species* usually attach to the head (within the ear, eye canthus, around neck), margin of the anus and under the tail. Long-hypostome species attach to the lower part of the body where the skin is thicker (like dewlap, axilla, groin, udder, testes, perineum and margin of the anus). Favourite attachment sites for *A. variegatum*, *A. gemma*, and *A. lepidum* are brisket, ventral surface, flank, udder/scrotum and sternum (Hoogstraal, 1956; Howell *et al*., 1978 and Petney *et al*., 1987)). Smaller ticks like *Boophilus* have not marked preference, and can be found all over the body (Morel, 1989). As observed by Howell *et al.* (1978) in South Africa the preferred feeding sites of *B. decoloratus* are neck, dewlap, belly and legs. In heavy infestation it may be found anywhere on the cattle body. According to Kaiser *et al*. (1982) observation in southern Uganda this species showed less preference to specific body regions of cattle.

2.3.4. Cattle resistance to ticks

Host tick resistance is the ability to limit the proportion of ticks maturing on it, and is described in terms of percentage survival or percentage mortality (Sutherst, 1987[b]). Different defence mechanisms, including tick avoidance, grooming, skin characteristics and more specific immunological responses, are involved in reducing the number of ticks parasitizing cattle (de Castro, 1991 and Minjauw and de Castro, 2000). Avoidance was attributed to the sighting of the ticks (de Castro, 1991).

Grooming is reported as a means by which the host can express resistance. Significantly fewer ticks were found on those animals that were able to groom (Brossard, 1998 and Minjauw and de Castro, 2000). According to the observation of de Castro (1991) African cattle (*Bos indicus*) naturally self-groom and groom each other frequently and thoroughly. It is known that cattle and laboratory animals acquire resistance to ticks as a consequence of exposure of hosts to natural infestation of ticks or as a result of artificial introduction of host antigens originally from salivary glands of ticks (FAO, 1984; Wikel and Whelen, 1986 and Rechav, 1992). Resistance of cattle to tick infestation was reported to consist of innate and acquired components. *Bos indicus* purebreds and crossbreeds were reported to be more innately resistant to *Bos microplus* infestation than *Bos taurus* breeds (Wikel and Whelen, 1986). Australian scientists with *Boophilus microplus* studied skin reactions of cattle to tick attachment. At the attachment point of the larva a papule develops surrounded by an oedematous patch of variable size depending on host resistance. Receptive animals show no irritation, and oedema is slight, whereas it is extensive in resistant animals (Morel, 1989).

Resistance may be spontaneous or acquired following infestations, due to the development of cutaneous hypersensitivity (Sutherst, 1987[b]; Tatchell, 1987 and Morel, 1989). The mechanism responsible for acquired resistance to ticks has been suggested to be a mast cell-dependent eosinophil hypersensitivity (Brown, 1985). Resistance can be passively transferred with viable lymph node cells but not with serum from resistant hosts. This passage method of tick resistance suggests a delayed hypersensitivity mechanism for the acquisition of resistance (Wikel and Allen, 1976). The blood histamine level have been found to be elevated as a result of cutaneous basophiles or mast cells increase in resistant hosts, which degranulate in the region of ticks attachment to produce histamine. The histamine has shown to stimulate detachment of *Boophilus microplus* larvae. But the infestation rate increases in normally resistant zebus either due to true inhibition by the allergic, or by reduced cutaneous pruritus that halts licking that enables to kill the larvae by resistant cattle (Brown, 1985; Wikel and Whelen, 1986; Morel, 1989 and Tatchell, 1987). Hence, host acquired resistance to tick is an immune-mediated phenomenon that results in the reduction in the number of attached and engorged ticks, the number of successfully fed ticks (smaller blood meals and decreased in weight of engorged female ticks), changes in the duration of feeding, the moulting success of fed immature ticks and the fecundity or the fertility of fed female ticks, which results in the failure of ticks to complete their development (Brown, 1985; Tatchell, 1987 and Rechav, 1992), there is reduced oviposition by those females which did feed and death of ticks at the attachment sites. Ticks, which obtained a blood meal from immunized animals, produce ova that cannot be hatched (Brown, 1985 and Wikel and Whelen, 1986).

Resistant hosts were characterized by allowing significantly fewer ticks to engorge and those, which did feed, were of a significantly lower weight than those from non-resistant hosts (Wikel and Allen, 1976 and Wikel and Allen, 1977). The study conducted by Wikel and Allen (1976) showed that larvae from a resistant host showed a marked reduction in engorgement with a mean weight one seventh that of larvae feeding on a non-resistant host. As observed by Dossa *et al*., (1996) and Tatchell, (1987) the principal component analysis was that percentages of adults and nymphs that engorged, percentage of adults and nymphs that died, and percentage of nymphs, which moulted, were the main indicators of resistance. Resistance by cattle to *Boophilus microplus* was mainly expressed during the first 24-48 hours of larval attachment. The expression of host resistance to adult tick is probably less successful than to immature (Dossa *et al*., 1996 and Tatchell, 1987). Hosts showing greater resistance than other hosts did so to all instars and species of ticks and cattle ranking in terms of tick burdens were highly repeatable (Solomon and Kaaya, 1996 and Tatchell, 1987). Field study in Africa where many species of ticks are abundant on cattle showed that animals which carried less number of one species also carried a lower number of other tick species (Kaiser *et al*., 1982 and Rechav, 1992). Tatchell (1987) observed that host resistance varies seasonally in Queens Land, declining in autumn and recovering in spring and varies from year to year for less well-understood reasons. In addition to these regular changes there are more obviously stress-related factors such as nutrition and lactation.

It has been recognized that various breeds of cattle differ in their response to tick infestations. Some breeds have the ability to reduce the number of ticks they carry and are considered resistant while others cannot control the number of ticks they carry and thus are referred to as sensitive breeds (Rechav, 1992). The research conducted to compare tick resistance in three breeds of cattle, two indigenous breeds, Arssi and Boran, and one cross breed, Boran x Friesian following natural tick infestations at Abernossa ranch in Ethiopia showed that Arssi breed have the highest tick resistance which carried only 10.3% of all ticks collected (Solomon and Kaaya, 1996). The least tick resistant cattle, Boran x Friesian, carried large number of ticks with highest survival periods, whereas the most resistant indigenous cattle, Arssi and Boran, carried lower number of ticks with the lowest survival periods (Solomon and Kaaya, 1998). The host resistance measured by the number of adult ticks on individual animals belonging to Boran, Barka and Horro indigenous breeds and the crosses with Jersey, Friesian and Simmental revealed the presence of better control of tick burdens in the local indigenous zebus (Yohualashet *et al*., 1995).

The various degree of susceptibility manifested as soon as larvae, and then nymphs and females are attached seems to be a genetic characteristic of individuals animals or breeds (Morel, 1989). A number of physiological and environmental factors can affect the level of host resistance to ticks or the expression of host resistance (FAO, 1984 and Rechav, 1992). Among which nutrition, sex, pregnancy, lactation, age (Sutherst, 1987[b] and Rechav, 1992), exposure to ticks, breed and tick density (FAO, 1984) play key roles. It was found that protein deficiency in the diet of cattle affects the level of resistance of cattle to ticks (Sutherst *et al.*, 1983 and Rechav, 1992). Hence good nutrition has a pronounced effect in maintaining high resistance to ticks (FAO, 1984). Male of various animals tend to carry more ticks than females, which might be related to the hormonal levels of the individual animals (Rechav, 1992). Cattle lose resistance with time, and it seems that the older the animal, the lower the resistance (Wharton *et al.*, 1970 cited by Sutherst, 1987[b]). Study conducted on indigenous cattle in a pastoral dry to semi-arid rangeland zone of Uganda showed that calves less than six months old had very low numbers of ticks (Okello-Onen *et al.*, 1999[b]). Pregnant cows were significantly more sensitive than non-pregnant female and carried a higher number of ticks mainly during the late stages of the pregnancy (Utech *et al.*, 1978). The stress of lactation causes a marked decline in the resistance of exotic breeds; it also affect Zebu, but to a much smaller extent (FAO, 1984). Okello-Onen *et al.* (1999[b]) observed more ticks on cows than on calves and lactating cows carried more ticks as compared to non-lactating cows on indigenous cattle in a pastoral dry to semi-arid rangeland zone of Uganda, except for *Amblyomma variegatum*, where the opposite was true. Stable resistance is acquired after several months of exposure to the species of tick to which resistance is required.

The success rate of tick in feeding is reduced when there are large numbers of them attaching to an animal simultaneously. Effects of density are lost when cattle are stressed by poor nutrition, which result in potentially large populations surviving on the stressed animals (FAO, 1984).

The overall significance of tick resistance is that maximizing the productivity through reducing the risk of losses in live weight gain, milk production and mortalities due to heavy tick infestation. High levels of resistance reduce the favourability of the environment for ticks (Sutherst, 1987[b]).

2.3.5. Dynamics of ticks

Tick populations in any particular environment, with a particular type of animals and management system, fluctuate about a long-term average size (Sutherst, 1987[a]). The size of the fluctuations depends partly upon the extent of variation in environment (Sutherst, 1987[a]; Kaiser *et al.* 1988; and Latif and Walker, 2004), but also upon the properties of the population of ticks themselves (Sutherst, 1987[a]). The number of females attached to the host is the most significant indicator of the seasonal activity and population dynamics of these ticks (Minjauw and McLeod, 2003).

Ticks distribution, abundance and seasonal dynamics directly determine the epidemiology of tick-borne diseases (Randolph, 1994; Sutherst, 1987[a] and Randolph *et al.* 2002). Randolph *et al*. (2002) observed that marked variation in *Ixodes ricinus* seasonal population dynamics have direct impact on the transmission of many pathogens vectored by this tick species. When tick numbers are very low (less than about five engorged adult female ticks per animals) transmission of Babesia is interrupted. This leads to delayed infection of new animals born into the herd (Sutherst, 1987[a]). The population dynamics of any organism are the product of the interaction of the demographic process, birth and death, which are determined, by both abiotic (climatic) and biotic (tick density) interactions (Randolph, 1994). The much greater seasonal variation in climatic conditions, particularly temperature, introduces variable development rates and diapauses into the life cycle (Randolph, 1997; and Latif and Walker, 2004). The proportion of the development of a tick, which takes place each day, depends on the temperature of its surrounding. Progress of the rate of development is directly related to temperature (FAO, 1984). According to Randolph (1994) observation on *Rhipicephalus appendiculatus* in South Africa the development rate, including the rate of egg production, declines with falling temperatures, but the fecundity although reduces by extremes of temperature, does not vary much within the temperature range normally encountered by ovipositing females.

Hence, tick development rates and host-questing activity is temperature-dependent (Randolph, *et al.* 2002). Abiotic and biotic variables suggest that it is the stage from female to larvae, which is most sensitive to adverse abiotic conditions, specifically low moisture availability, dryness (Randolph, 1994; and Latif and Walker, 2004). Non-climatic factors were apparently important in determining the relative numbers of *Amblyomma variegatum* in different regions (Kaiser *et al.*1998).

Two different mechanisms always operate with intensities that vary in proportion to the sizes of tick populations. First, the success rate of larval ticks on pastures in finding a host is strongly dependent upon the density of larvae in the pastures (Sutherst *et al*. 1986). At high population densities the cattle are able to detect and avoid dense clumps of larvae on the pastures. The growth of tick populations is therefore slowed progressively as the density of larvae on the pasture increases (Sutherst, 1987[a]). Second, once the larvae succeed in attaching to an animal, their success in feeding on that animal will also be dependent upon the number of larvae attaching (Sutherst and Utech, 1981). About 10% of larvae attaching to *Bos indicus* were survive to maturity when 100 larvae attach, whereas only 1% of those larvae survive when 20,000 larvae attach. Similarly for *Bos taurus* up to 30% of the larvae may survive at a density of 100-larvae/ animals but only 10% when 20,000 larvae attach (Sutherst, 1987[a]).

Economic losses normally associated with heavy infestation in which tick numbers cause increasing losses as the population increases in size (Sutherst *et al*. 1986 and Sutherst, 1987[a]). Therefore, a more precise assessment of the economic impact of ticks will depend on a better knowledge of the distribution, population dynamics and ecology of ticks in different region (Mekuria, 1987).

2.4 Economic importance of ticks

Ticks pose a considerable threat to human and animals all over the world (Brossard, 1998). It is the feeding of ticks that makes them important in the health of livestock (Walker *et al*., 2003; and Latif and Walker, 2004). All feeding of ticks at each stage of their life cycle are parasitic (Latif and Walker, 2004). It has been estimated that 80% of world's cattle are infested with ticks, and approximately one thousand two hundred fourteen million world cattle at risk from ticks and tick-borne diseases (Minjauw and McLeod, 2003). Recently de Castro (1997) estimated that the annual global cost associated with tick and TBD in cattle amounted to between US $13.9 and US $18.7 billion. According to Morel (1980), the effect of ticks broadly classified as direct pathogenic and indirect pathogenic effect.

All the direct pathogenic effect of ticks occurs at the time of or/and following feeding (Latif and Walker, 2004). During feeding ticks cause diseases to their hosts by taking blood, injuring the skin, causing irritation and pain, udder damage and injection of toxins (Katherine, 1976; FAO, 1984; Morel, 1989; Hopla *et al*. 1994; and Latif and Walker, 2004). Being ticks are voracious blood feeder's heavy infestations can results in anaemia (Jongejan and Uilenberg, 1994 and Wall and Shearer, 1997). In natural infestation that involves thousands of ticks/animal the anaemia can be severe (Kaufman, 1989). The local injury developed at the site of attachment may predispose to secondary bacterial infection and to screw worm myiasis (Katherine, 1976, Jubb *et al*., 1993 and Brossard, 1998). With their powerful mouthparts ticks damage the skin of animals, and leads to reductions in the leather quality and consequently to considerable economic losses (Brossard, 1998). Deep and painful bite wound is more severe in long mouthpart ticks, *Amblyomma* and *Hyalomma*. Deep bite often leads to abscess formation due to infection by pyogenic bacteria, and damage to udder (Jubb *et al*., 1993). The irritation and painful phenomenon that followed tick bite result in worry or annoyance. Hence, the host expend much of its time and energy in effort to avoid this effect rather than grazing (Katherine, 1976; Kaufman, 1989 and Morel, 1989).

Ticks can be a direct cause of illness, toxicosis and tick paralysis (Brossard, 1998). Some species of ticks known to introduce toxins through their salivary secretions into the host blood stream while feeding. These toxins act like neurotoxins producing ascending paralysis, or responsible for tick-borne toxicosis (Katherine, 1976 and Morel, 1989). Ticks like *Ixodes* species, *Dermacentor andersoni, Haemaphysalis punctata*, *Hyalomma aegyticum, Rhipicephalus evertsi evertsi, Rhipicephalus simus* and *Amblyomma cajannese* reported to be responsible for tick paralysis (Katherine, 1976), while *Hyalomma truncatum* and *Rhipicephalus appendiculatus* able to cause tick toxicosis, sweating sickness, that seen in southern and east Africa (Katherine, 1976 and Morel, 1989).

The indirect pathogenic effect of tick manifested principally through their ability to transmit a wide spectrum of pathogenic microorganisms (FAO, 1984). When these microorganisms infect ticks, the ticks able to transmit them to livestock (Latif and Walker, 2004). In Africa, the major tick-borne cattle diseases are East coast fever, babesiosis, cowderiosis, tropical theileriosis, anaplasmosis and dermatophilosis (Jongejan and Uilenberg, 1994). Except the former the later diseases are known to present in Ethiopia (Morel, 1989).

2.5. Review of tick distribution in Ethiopia

In Ethiopia ticks are common in all agro-ecological zones of the country (Bergeon and Balis, 1974; Morel, 1980; Pegram *et al*., 1981 and Mekonnen, 1998). They are economically very important, which are vector of babesiosis, anaplasmosis, cowderiosis, tropical theileriosis and dermatophilosis in Ethiopian cattle (Morel, 1980 and Mekonnen, 1998).

Early tick studies in Ethiopia were by Pavesi around 1983 to 1984, Pocock in 1900 and Neumann in 1902 and 1922 as cited by Pegram *et al*. (1981). Ticks common to Ethiopia and Sudan were listed by Hoogstraal (1965). Then in 1970's and beginning of 1980's ticks of the country studied by Bergeon and Balis (1974), Morel (1980) and Pegram *et al*. (1981) respectively. After the establishment of Faculty of Veterinary Medicine the work done by various researchers and study conducted by graduating class student as partial fulfilment of DVM degree, DVM thesis, in some parts of the country is reviewed and mapped as presented as Annex 9. The most common tick genera in Ethiopia include *Amblyomma, Boophilus, Rhipicephalus* and *Hyalomma.*

Amblyomma: Of the genus Amblyomma four species that commonly infest cattle, which includes *Amblyomma variegatum, Amblyomma gemma, Amblyomma lepidum and Amblyomma cohaerens* are known to exist in Ethiopia (Morel, 1980; de Castro, 1994 and Walker *et al*., 2003). The observations of Naser (1985) and G/Michael (1993) in Wolayta, Abdo (1986) in Gamo-gofa, Biru (1988) in Southern Sidamo, Gardie (1988) in Bale, Solomon *et al* (1998) in Didytuyura and Regassa (2001) in Borana showed that *Amblyomma variegatum, Amblyomma gemma, Amblyomma lepidum* distributed in wider areas of southern Ethiopia. Assefa (2004) found in Asella *Amblyomma variegatum* was the most spread tick species, and *Amblyomma cohaerens* was the fourth abundant species; in spite of this it is the second abundant Amblyomma species. But *Amblyomma variegatum* and *A. lepidum* are the most wide spread species of the genus in northern part of the country (Mamo, 1988; Abera, 1989; Yilma *et al*., 1995; Mesfin, 1996; Sinshaw, 2000 and

Seyoum, 2001), but *Amblyomma gemma* and *Amblyomma cohaerens* also recorded in Wollo (Yilma *et al*., 1995 and Seyoum, 2001). From the study of Bergeon and Balis (1974), Morel (1980), Pegram *et al*. (1981), Haile (1987) in Illubabor, Mekuria (1987) in Nekemte, and De Castro (1994) in western Ethiopia *Amblyomma variegatum* and *Amblyomma cohaerens* are widely distributed in western Ethiopia. But according to Getachew (2004) and Belay (2004) observations in Jimma area and around Mizan-Teferi respectively *Amblyomma cohaerens* is the most abundant species. *A. variegatum* and *A. cohaerens* are the two most prevalent top *Amblyomma species* in Awassa areas in decreasing order (Berhane, 2004). *Amblyomma variegatum* and *Amblyomma gemma* is the most widely spread species of *Amblyomma* in eastern Ethiopia (Asrat, 1987; Hatsur, 1991; Tadesse, 1996; and Bekele, 1996). From the observation of Mekonnen (1994) and Bergeon and Balis (1974) the presence of all the four species in central part of the country are known with *Amblyomma variegatum* and *Amblyomma cohaerens* more spread than the others. The species of *Amblyomma* in decreasing order of abundance in central Ethiopia is *Amblyomma variegatum, Amblyomma cohaerens, Amblyomma lepidum and Amblyomma gemma* (Mekonnen *et al*., 2001). From them *Amblyomma gemma* is more common in east and north Shewa, and Afar region (Morel, 1980; Pegram *et al*., 1981 and Mekonnen *et al*., 2001). *Amblyomma variegatum,* "Tropical bont tick" (Wellcome, 1976; Howell *et al*., 1978 and Walker *et al*., 2003), occur in all agro-ecological zones, but in varying level of abundance, which are more prevalent in higher good rainfall areas (Morel, 1980; Pegram *et al*., 1981 and de Castro, 1994). It predominates in forest and wooded grasslands (Pegram *et al*., 1981). *Amblyomma gemma*, "Gem-like bont tick" (Susan, 1998), recorded from areas ranging from temperate or highland, through steppe to desert mainly in eastern and southern Ethiopia (Pegram *et al*., 1981; de Castro, 1994 and Walker *et al*., 2003). It is clearly associated with dry types of vegetation or semi-arid rangelands (Morel, 1980 and Pegram *et al*., 1981). *Amblyomma lepidum*, "East African bont tick"(Wellcome, 1976 and Susan, 1998), most commonly inhabits arid habitats with 250-750mm rainfall and in open bushed shrub or wooded grassland (de Castro, 1994 and Walker *et al*., 2003). Its distributions overlap with *Amblyomma gemma* and that of *Amblyomma variegatum*. The species is common but not particularly abundant (Morel, 1980). *Amblyomma cohaerens*, "East African Buffalo Bont tick" (Hoogstraal, 1956) distribution believed to be associated to wild hosts, particularly African buffalo, *Syncerus caffer*. It is hardly abundant at lower altitude and rainfall (Morel, 1980 and de Castro, 1994). Pegram *et al*. (1981) and de Castro (1994) found that it is the most abundant in the western part of Ethiopia. It seems to subsist normally on cattle where the initial host disappeared (Morel, 1980).

Boophilus: Two species of this genus are known to exist in Ethiopia, which include *Boophilus decoloratus* and *Boophilus annulatus. Boophilus annulatus,* "Texas fever tick" (Wellcome, 1976), is known to present in Gambiella region (Pegram *et al*., 1981; Haile, 1987and de Castro, 1994). The study done by Bergeon and Balis (1974), Morel (1980), Pegram *et al*. (1981), Naser (1985) and G/Michael (1993) in Wolayta, Abdo (1986) in Gamo-gofa, Asrat (1987) and Hatsur (1991) in Harrarge, Haile (1987) in Illubabor, Mekuria (1987) in Nekemte, Biru (1988) in southern Sidamo, Gardie (1988) in Bale, Mamo (1988) in Gondar, Abera (1989) in Bahir-Dar, de Castro (1994), Tadesse (1994) in Dire-Dawa, Yilma *et al*. (1995) and Seyoum (2001) in Wollo, Bekele (1996) in eastern zone of Ethiopia, Mesfin (1996) in Tigray, Solomon *et al*. (1998) in Didytuyura, Sinshaw (2000) in

Metekel Ranch, Mekonnen *et al*. (2001) in central Ethiopia, Regassa (2001) in Borana, Bekele (2002) in Alemaya, Assefa (2004) in Asella, Belay (2004) in and around Mizan-Teferi, Berhane (2004) in Awassa and Getachew (2004) in Jimma indicated that *B. decoloratus,* "The Blue tick" (Wellcome, 1976; Howell *et al*., 1978 and Walker *et al*., 2003), because of the colour of engorged female, is the most abundant and widespread tick species throughout the country . It predominates in broad-leaved and coniferous forest, but absent from drier areas (Pegram *et al*., 1981 and de Castro, 1994).

Hyalomma: Up to now about eight species of Hyalomma that affect cattle are identified, which includes *Hyalomma marginatum rufipes, Hyalomma dromedarii, Hyalomma tuncatum, Hyalomma marginatum marginatum, Hyalomma impelatum, Hyalomma anatolicum excavatum, Hyalomma anatolicum anatolicum* and *Hyalomma albiparmatum. Hyalomma dromedarii*, “The camel hyalomma” (Wellcome, 1976 and Walker *et al*., 2003) is the most adapted to conditions of drought or semi-deserted areas. Its natural distribution coincides with that of nomadic pastoralists and their camels (Morel, 1980 and Pegram *et al*., 1981). Altitude is not a limiting factor as long as host animal population and favourable conditions exist (Morel, 1980 and de Castro, 1994). It is mainly recorded from central (Morel, 1980 and Mekonnen *et al*., 2001), northern (Morel, 1980 and Yilma *et al*., 1995), eastern (Asrat, 1987; Hatsur, 1991; Tadesse, 1994; Bekele, 1996; Bekele, 2002 and Walker *et al*., 2003) and southern (Biru, 1988 and Gardie, 1988) Ethiopia.

Hyalomma marginatum rufipes, “The hairy *Hyalomma* or The coarse-legged *Hyalomma*” (Walker *et al*., 2003) distribution is relatively continuous and regular that is throughout the country (Pegram *et al*., 1994), more in humid areas, because of the xerophilic characteristics of the species. It finds its biotopes in open or very open vegetal formations, on heights rather than lowland. But it is recorded from desert to rainforest areas of the country (Bergeon and Balis, 1974; Morel, 1980; Pegram *et al*., 1981; Naser, 1985; Abdo, 1986; Asrat, 1987; Haile, 1987; Mekuria, 1987; Biru, 1988; Gardie, 1988; Abera, 1989; Hatsur, 1991; de Castro, 1994; Tadesse, 1994; Yilma *et al*., 1995; Bekele, 1996; Mesfin, 1996; Solomon *et al*., 1998; Sinshaw, 2000; Mekonnen *et al*., 2001; Seyoum, 2001; Regassa, 2001 and Assefa, 2004).

Hyalomma truncatum, "The shiny or African Hyalomma" (Wellcome, 1976 and Walker *et al*., 2003) is adapted to dry habitats and is commonest in desert, steppe and savannah climatic region, but also recorded from highland (de Castro, 1994 and Walker *et al*., 2003). It is recorded from different ecological zones of the country by various investigators in different period of time (Bergeon and Balis, 1974; Morel, 1980; Pegram *et al*., 1981; Abdo, 1986; Asrat, 1987; Biru, 1988; Mamo, 1988; Hatsur, 1991; Yilma *et al*., 1995; Mesfin, 1996; Solomon *et al*., 1998; Mekonnen *et al*., 2001; Regassa, 2001; Seyoum, 2001 and Assefa, 2004).

Hyalomma anatolicum excavatum's, "The small Hyalomma" (Wellcome, 1976) most specimens are collected from camels (Morel, 1980; Pegram *et al*., 1981; Gardie, 1988 and Yilma *et al*., 1995). Its habitat corresponds to the Somali xerophytic and sub-desertic steppes (Morel, 1980 and Walker *et al*., 2003).

Hyalomma impelatum occurs mainly in steppe and desert climate, and its distribution is somewhat more extensive than those of other xerophilic species of Hyalomma (Morel, 1980; Pegram *et al*., 1981; Asrat, 1987; Biru, 1988; Bekele, 1996; Seyoum, 2001; Bekele, 2002 and Walker *et al*., 2003).

Rhipicephalus: The most commonly encountered species on cattle are *Rhipicephalus evertsi evertsi, Rhipicephalus bergeoni, Rhipicephalus praetextatus, Rhipicephalus simus, Rhipicephalus pravus* and *Rhipicephalus pulchellus*. Others species that are rarely observed in some areas of the country includes *Rhipicephalus lunulatus* in Bale, Nekemte, Keffa and Illubabor (Bergeon and Balis, 1974; Pegram *et al*., 1981; Haile, 1987; Mekuria, 1987; Gardie, 1988; de Castro, 1994 and Walker *et al*., 2003), and *Rhipicephalus muhasmae* in Borana (Bergeon and Balis, 1974; Regassa, 2001and Walker *et al*., 2003), in wetter western areas of the country (Pegram *et al*., 1981 and de Castro, 1994) and in Arssi (Morel, 1980). *Rhipicephalus lunulatus* parasitizes chiefly cattle and is active only during rainy season (Pegram *et al*., 1981). Morel (1980) and Seyoum (2001) recorded *Rhipicephalus humoralis*, *Rhipicephalus cliffordi*, *Rhipicephalus compositus* and *Rhipicephalus distinctus* in Girana valley of Wollo and Northeast areas. *Rhipicephalus cliffordi, Rhipicephalus compositus* and *Rhipicephalus senegalensis* as cited by de Castro (1994) recorded from western Ethiopia by Pegram (1979). They are mainly parasite of buffalo (*Syncerus caffer*) and warthog (*Phacochoerus aethiopicus*), but were found on cattle, which probably indicating the presence of these wild animals in the area (de Castro, 1994).

According to the observation of Bergeon and Balis (1974), Morel (1980), Pegram *et al*. (1981), Naser (1985) and G/Michael in Wolayta, Abdo (1986) in Gamo-gofa, Asrat (1987) and Hatsur (1991) in Harrarge, Haile (1988) in Illubabor, Mekuria (1987) in Nekemte, Biru (1988) in southern Sidamo, Mamo (1988) in Gondar, de Castro (1994) in Western Ethiopia, Tadesse (1994) in Dire-Dawa, Yilma *et al*. (1995) and Seyoum (2001) in Wollo, Bekele (1996) in Eastern Ethiopia, Mesfin (1996) in Tigray, Sinshaw (2000) in Metekel Ranch, Assefa (2004) in Asella, Berhane (2004) in Awassa area and Getachew (2004) in Jimma *Rhipicephalus evertsi evertsi*, "Red-legged tick" (Wellcome, 1976; Howell *et al*., 1978; Okello-Onen *et al*., 1999[a] and Walker *et al*., 2003), is the most widespread species of *Rhipicephalus*. This species is the fifth prevalent in Awassa area (Berhane, 2004). It is mostly associated with Masai steppe, thicket and bamboo Nilotic savannah (Morel, 1980; Pegram *et al*., 1981; de Castro, 1994 and Walker *et al*., 2003).

Rhipicephalus pulchellus, "Zebra tick" (Wellcome, 1976; Okello-Onen *et al*., 1999[a] and Walker *et al*., 2003), is distributed widely in the north eastern (Morel, 1980; Pegram *et al*., 1981; Yilma *et al*., 1995; Mesfin, 1996; Seyoum, 2001 and Walker *et al*., 2003), eastern (Bergeon and Balis, 1974; Morel, 1980; Pegram *et al*., 1981; Asrat, 1987; Hatsur, 1991; Tadesse, 1994; Bekele, 1996 and Walker *et al*., 2003) and southern (Bergeon and Balis, 1974; Morel, 1980; Pegram *et al*., 1981; Naser, 1985; Abdo, 1986; Biru, 1988; Gardie, 1988; G/Michael, 1993; Solomon *et al*., 1998 and Regassa, 2001) part of the country. It is often abundant on cattle in the Rift Valley and eastwards inhabiting dry, semi-arid and bush land (Pegram *et al*., 1981 and Walker *et al*., 2003). According to Pegram *et al*. (1981) several cattle in Borana were parasitized by more than one hundred *Rhipicephalus* *pulchellus*, which is an approximate count in situ. Berhane (2004) reported that it is the third most abundant tick species in Awassa area.

Rhipicephalus simus, "Glossy tick" (Howell *et al*., 1978; Okello-Onen *et al*., 1999[a] and Walker *et al*., 2003), found in southern (Bergeon and Balis, 1974; Morel, 1980; Pegram *et al*., 1981; Naser, 1985; Abdo, 1986; Biru, 1988; Gardie, 1988; G/Michael, 1993 and Solomon *et al*., 1998), northern (Bergeon and Balis, 1974; Morel, 1980; Pegram *et al*., 1981; Mamo, 1988; Yilma *et al*., 1995; Mesfin, 1996 and Sinshaw, 2000), eastern (Bergeon and Balis, 1974; Morel, 1980; Pegram *et al*., 1981; Asrat, 1987 and Bekele, 1996), western (Pegram *et al*., 1981; Mekuria, 1987 and Haile, 1988) and central (Bergeon and Balis, 1974; Morel, 1980; Pegram *et al*., 1981 and Mekonnen *et al*., 2001) Ethiopia.

3. MATERIAL AND METHODS

3.1 Study area

Three agro-ecological zones, shown in Figure1, were chosen to represent the different agro-ecological zones in Wolayta (Wolayta Zone Agricultural Department, 2003). Wolayta Zone is located in Southern Nation Nationalities People Regional State; at 6.4º – 7.2º N and 37.4º – 38.2º E (Wolayta Zone Finance Economic Development Department, 2003). It has a total land area of 438,370 hectares, out of which 51.7% is cultivated land, 6.4% is cultivable, 11.9% is grazing land and 30% is others. The altitude of the area ranges from 1200-2950m above sea level (Wolayta Zone Agricultural Department, 2003). The total human populations estimated to be 1,594,617 as projected from 1994 census. The average crude population density of the Zone is 342 person/Km² (CSA, 2003 and Wolayta Zone Finance Economic Development Department, 2003). The main occupation of rural population is mixed farming practice whereby crop and livestock are managed hand-in-hand together. The livestock populations that are found in Wolayta Zone include cattle, sheep, goats, horses, mule, donkey and poultry (CSA, 2003; Wolayta Zone Agricultural Department, 2003). The cattle population is estimated to be 658,886 of which about 3,825 is Holstein cross. The cattle population in Wolayta accounts for 7.46% of the SNNRPS total cattle population (CSA, 2003). The maximum and minimum land holdings per household are 0.5 and 0.125 hectare respectively (Wolayta Zone Finance and Economic Development Department, 2003). The area is characterized by bimodal rainfall, long rainy period (June to mid of October) and short rainy period (March and April). According to FAO.AGAL (2003) the midland and highland areas of Wolayta is characterized by two growing periods per year, but the lowland areas characterized by single growing period per year.

The study sites were:

- Dalbo-Woganie (Highland)- Which is greater than 2493 meter above sea level, found on Damota Mountain, and located between 6^0 53' 22.9" to 6^0 55' 45.2" N latitude and 37^0 48' 03.1" to 37^0 49' 06.2" E longitude (Measured using GPS). Predominant vegetation is eucalyptus tree, natural grasses and tuft of grasses. Farmers in the area commonly produce crops like wheat, barely, bean, enset and root crops.

- Kokatie (Midland)- This study site is 2083-2213 meters above sea level, and located between 6^0 52' 01.9" to 6^0 52' 42.6" N latitude and 37^0 47' 06.9" to 37^0 48' 55.3" E longitude. The area is with eucalyptus tree, natural grasses and tufts of grasses the predominant vegetation. The common crops of the area are wheat, barely, enset, maize and root crops.

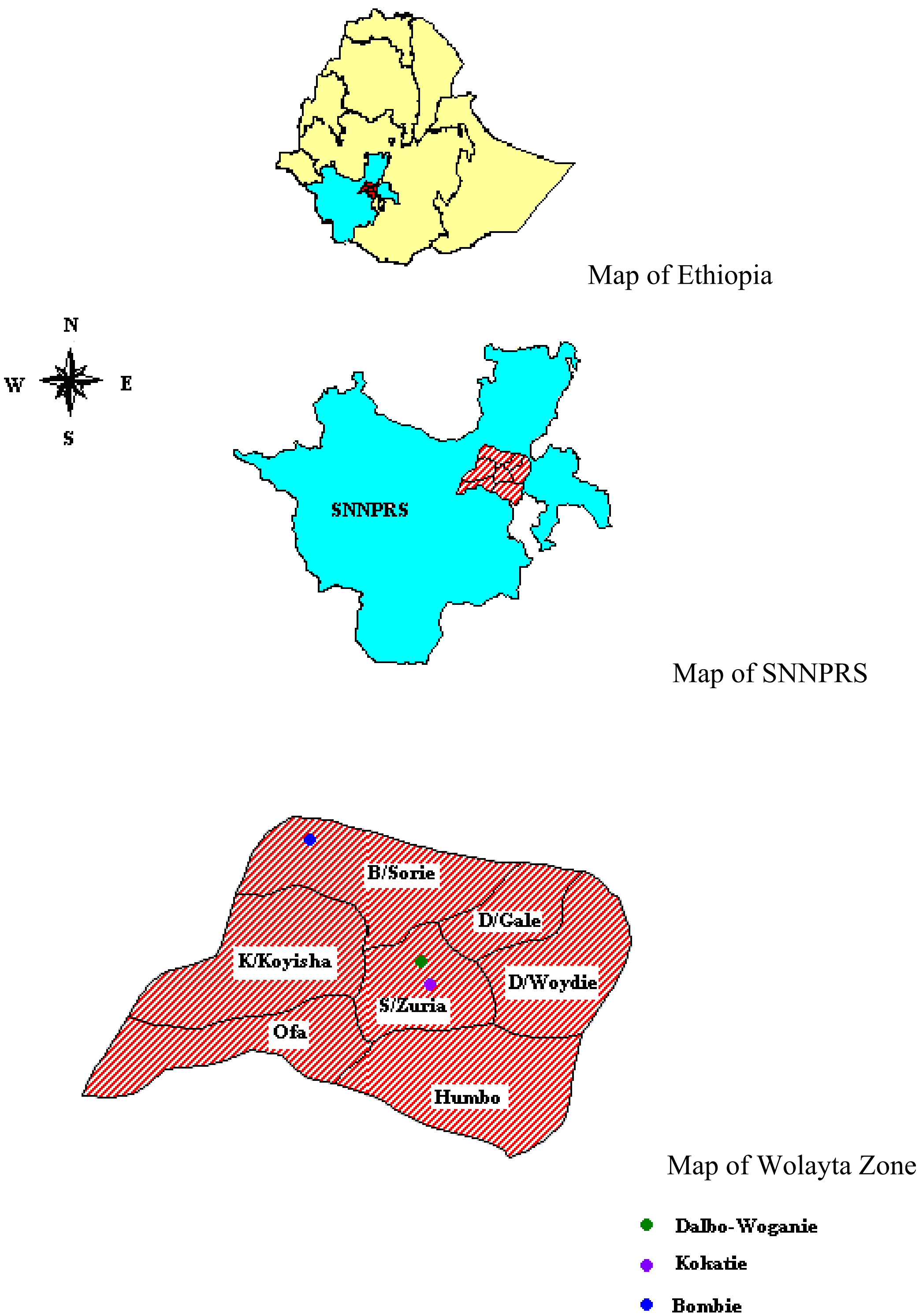


Figure 1. Map of Ethiopia and the study sites.

- Bombie (Lowland) - It is an area with 1347 -1495 meters above sea level, and found between 7^0 8' 12.4" to 7^0 9' 13.5" N latitude and 37^0 34' 56.4" to 37^0 36' 0.8" E longitude. The area is wet lowland. The dominant vegetations of the area include shrub, eucalyptus tree, natural grasses and some tufts of grasses. The major crops of the area include maize, enset, coffee, teff, ginger and root crops.

3.2 Study population

The cattle population is estimated to be 658,886 of which about 3,825 is Holstein crosses (50%). The cattle population in Wolayta accounts for 7.46% of the SNNRPS total cattle population (CSA, 2003). The cattle population in Wolayta, especially in rural areas, depends on natural grasses and crop residues, and kept in traditional backyard management system (CSA, 2003). The total grazing areas is about 11.9% of the total land. Most of the animals (94.4%) are indigenous breed and only 0.6% of them are Holstein crosses (50%).

3.3 Study animals

Sixteen indigenous cattle breed selected by systematic random sampling technique from each agro-ecological zones of the study areas, and similarly sixteen Holstein cross (50%) crossbreed selected from midland for this study. These animals were not treated with any acaricides during the study periods of tick burden counting.

One hundred thirty eight cattle were selected by systematic random sampling technique for ticks collection and identification from eight half-body regions of cattle: Head, Dewlap, Brisket, Belly and back, Udder or Scrotum, Anogenital, Leg and Tail during wet period. Similar sample sizes of cattle were used for similar purpose during dry period. The pictorial representation of the body regions used for tick sampling shown on Annex 7.

3.4 Study design

The study design consists of longitudinal study to assess the monthly total tick burden in all the three agro-ecological zones on selected cattle. The other part of the study design was cross-sectional study, which is to assess the adult tick present in the area during wet and dry periods.

3.5 Study Methodology

Adult ticks collection for identification and total tick burden counting were performed on half-body regions of cattle.

Tick collection and identification

Adult ticks were collected from half-body regions of cattle from the three agro-ecological zone during wet and dry periods into universal sample bottle containing 70% ethanol (Okello-Onen *et al*., 1999[a] and Walker *et al*., 2003). The half-body regions used for collections were head, dewlap, brisket, belly and back, udder/ scrotum, Anogenital region, leg and tail (Modified from Kaiser *et al*.,) 1982 as shown on Annex 8. Ticks were removed from the host skin whilst retaining their good condition for identification using good quality steel forceps. The collected adult ticks from each body regions were kept separately for identification in separate sample bottles. Then ticks taken to Soddo Zonal Veterinary Laboratory and identified using stereomicroscope following the standard identification procedures described by Hoogstraal (1956), Okello-Onen *et al*. (1999[a]) and Walker *et al*. (2003).

Tick burden counting

In each of the three agro-ecological zones half-body total tick burden of above mentioned body regions of sixteen indigenous cattle counted monthly from August 2004 to March 2005, for eight months. During the same study period in the midland total tick burden of similar body regions of sixteen Holstein crossbreed were counted for similar periods of time. All tick species and any developmental stages, total tick; present on right side of the study animal was counted monthly by dividing the animal body into head, dewlap, brisket, belly and back, udder/ scrotum, Anogenital region, leg and tail (Modified from Kaiser *et al*., 1982; Dreyer *et al*. 1997 and Okello-Onen, 1999[a]). To find any immature or unfed adult ticks the animals' hairs parted systematically using forceps as described Kaiser *et al*. (1991), de Castro (1994) and Okello-Onen (1999[a]).

3.6 Sampling and sample size

The study kebeles' were selected by purposive sampling technique. But the study cattle, sixteen indigenous breeds from each agro-ecological zone sampled by systematic random sampling technique, and additionally Holstein crossbreeds in similar way sampled from midland, Kokatie. To assess tick species present in the three agro-ecological zones in wet and dry periods cattle selected from each study sites by systematic random sampling technique during each period. The sample size was determined using the formula given by Thrusfield (1995) based on Naser (1985) and G/Michael (1993) investigation that revealed 90% of the total animals in Wolayta were infested by ticks. The study considers 95% level of significance.

$$\mathbf{N = 1.96^2 \; X \; P_{exp} \; (1\text{-}P_{exp}.) \; / \; d^2 = 138}$$

Where **N =** required sample size

$\mathbf{P_{exp}}$ = expected prevalence

d = desired absolute precision

Therefore, from each agro-ecological zone 138 cattle sampled by systematic random sampling technique. Then adult ticks were collected from half-body regions of eight different body parts of cattle during wet periods. Also during dry period 138 cattle sampled by similar sampling technique. The cattle population of Dalbo-Woganie, Kokatie and Bombie were 1764, 2617 and 2019 respectively. Hence their sampling fractions found to be 1/13, 1/19 and 1/15; then the random number 10 selected for conveniences in the three study sites. Every tenth animal was taken when they were moving for watering or allowed for grazing. After that adult Ixodid ticks were collected from eight half-body regions of the animal body into separate sample bottle. All the collected adult ticks were identified to species level using stereomicroscope at Soddo Zonal Veterinary Laboratory with in one week of the collection.

3.7 Data analysis

After entry of the collected data into the Microsoft Excel sheet, it was summarized by descriptive statistic like mean and percentage, and then displayed by graphs and table. Before doing statistical analysis half-body regions total tick counts were transformed in to logarithmic form to have log-normal distribution. Analysis of variance, t-Test, X^2 and adjusted univariate approach of repeated measure of analysis of variance were used to test the seasonal and agro-ecological differences of species identified, and the burden difference in agro-ecological zones, between seasons and breeds respectively. For these analyses Microsoft Excel and SPSS 11.5 (SPSS Inc., 1989-2002 LEAD Technologies) were used.

3.8 Meteorological data

Monthly weather data for April 2004 to March 2005 were received from Areka Agricultural Research Institute for Bolosso-Sorie, Bombie and from NMSA for Soddo-Zuria, Kokatie.

Soddo areas received 1112.3mm and Areka areas received 1033.2mm annual rainfall. The average annual humidity of Soddo and Areka were 63.49% and 60.93% respectively. The annual mean maximum and minimum temperature of Soddo and Areka were 25.38^{0}C and 26.59^{0}C, and 14.52^{0}C and 15.47^{0}C respectively. One year records (April 2004 – March 2005) of mean monthly data of rainfall in mm, humidity in %, maximum and minimum temperature in ^{0}C at Soddo Meteorological Station and Areka Agricultural Research Institute, which includes the study periods was shown on Table 1. The meteorological data from these two stations were used for the midland and lowland study sites, because the area is relatively homogeneous and such data were not available on the spot of sites.

Table 1. Meteorological data for the year April 2004 to March 2005.

Data type	Sites	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Rainfall	Soddo	277.8	105.7	103.3	185.2	159.3	63.4	93.0	39.2	27.7	8.2	8.5	41.0
	Areka	233.1	106.7	116.3	149.6	119.5	44.4	25.6	29.0	25.3	3.5	4.2	176.0
Humidity	Soddo	75.0	73.3	73.0	76.7	78.0	75.3	59.3	57.0	52.0	47.3	49.0	46.0
in %	Areka	73.2	72.2	71.2	74.6	76.9	73.4	56.9	46.5	48.3	45.6	39.3	53.1
Max. temperature	Soddo	25.2	25.1	23.1	22.3	22.7	23.9	25.1	26.5	27.3	27.6	27.3	28.5
	Areka	26.8	26.1	23.9	23.5	23.2	24.1	25.4	27.6	29.9	29.6	30.9	28.1
Min. temperature	Soddo	15.1	15.1	14.0	13.8	14.4	14.0	13.4	14.4	14.6	13.9	15.5	16.0
	Areka	16.3	14.7	14.6	14.2	14.6	14.4	14.0	16.0	16.1	16.3	17.5	16.9

Source: NMSA and Areka Agricultural Research Institute.

4. RESULT

4.1 Tick species identified

4.1.1 Proportion and distribution significance of tick species

A total of 12,182 adult Ixodid ticks were collected from half body regions of 412 cattle that sampled from the three agro-ecological zones during wet and dry periods. Of these collected ticks 6,460 were males and 5,722 were females. As a whole in the study areas four adult Ixodid ticks genera and eleven species were identified in wet period, and three adult Ixodid ticks genera and nine species were identified during dry period. During wet period the genera identified were *Amblyomma*, *Boophilus*, *Rhipicephalus* and *Hyalomma*. But in dry period *Amblyomma*, *Boophilus* and *Rhipicephalus* were identified. The proportions of tick genera identified from highland, midland and lowland during wet and dry periods were shown on Figure 2.

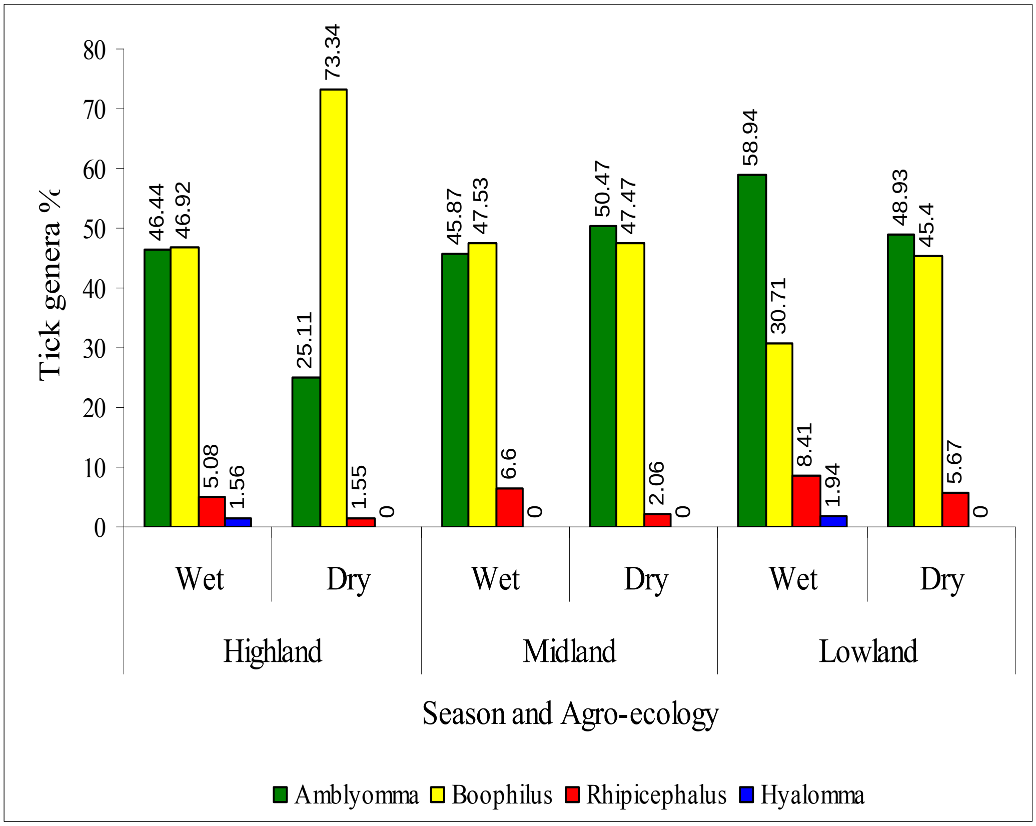


Figure 2. Percentages of tick genera identified during wet and dry periods.

From highland, Dalbo-Woganie, 2046 and 1617 adult ixodid tick species were collected from half-body regions of 138 cattle in wet and dry periods respectively. Then ten tick species were identified from this collection (shown on Figure 3). The most abundant tick species during wet period at Dalbo-Woganie is *B. decoloratus* (46.92%), and the least was *Rh. praetextatus* (0.39%). During dry period *B. decoloratus* (73.35%) was the most abundant tick species, and *Rh. muhsamae* (0.25%) was the least identified tick species.

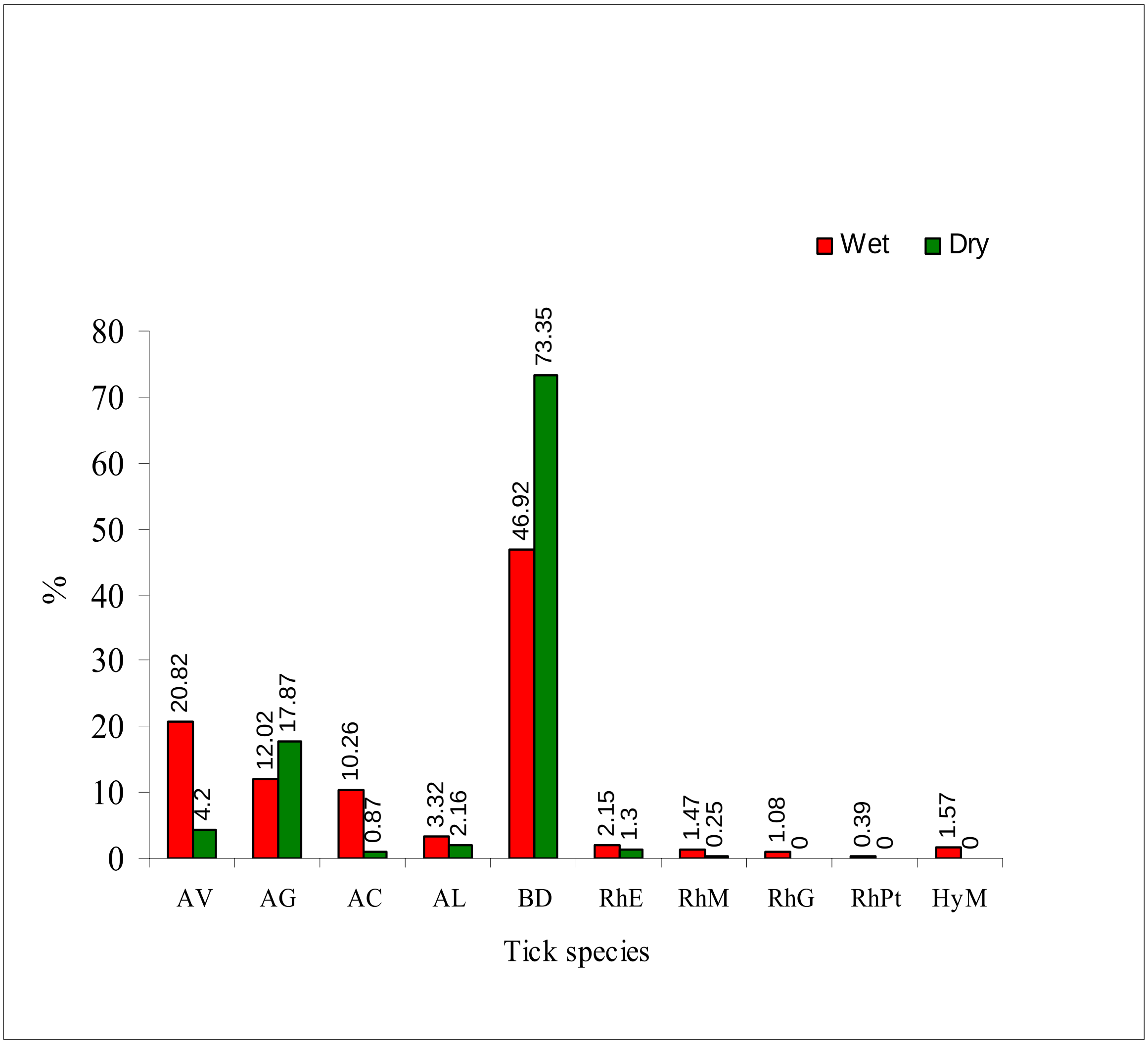


Figure 3. Tick species identified during wet and dry periods at highland, Dalbo-Woganie.

The proportion and descending order of each species abundance can be observed from Figure 3. At Dalbo-Woganie the proportion of *A. variegatum* and *A. cohaerens* were higher during wet, but that of B. *decoloratus* was maximum during dry period. These three species show highly significant seasonal variation at Dalbo-Woganie (t=7.6371, P=0.0000; t=6.3934, P=0.0000 and t=-3.5869, P=0.0004 respectively). Analysis of the seasonal variation of the major species at highland shown on Table 2.

Table 2. Seasonal variation of the major tick species at highland tested by two-sample t-Test with equal variances

Tick spp.	Season	Mean	Std. Deviation	Std. Error	t - value	df	P > |t|	[95% Conf. Interval]	Significance
AV	Wet	3.087	3.824	0.325				2.443 - 3.731	
	Dry	0.493	1.141	0.097	7.6371	274	0.0000	0 .301 - 0.685	* * *
AG	Wet	1.783	2.739	0.233				1.322 - 2.244	
	Dry	2.094	3.030	0.258	-0.8962	274	0.3709	1.584 - 2.604	NS
AC	Wet	1.522	2.552	0.217				1.092 - 1.951	
	Dry	0.101	0.544	0.046	6.3934	274	0.0000	0.010 - 0.193	* * *
AL	Wet	0.493	1.234	0.105				0.285 - 0.700	
	Dry	0.254	0.846	0.072	1.8777	274	0.0615	0.111 - 0.396	NS
BD	Wet	6.957	3.518	0.299				6.364 -7.549	
	Dry	8.594	4.048	0.345	-3.5869	274	0.0004	7.913 - 9.276	* *
RhE	Wet	0.319	1.025	0.087				0.146 - 0.491	
	Dry	0.152	0.627	0.053	1.6295	274	0.1043	0.047 - 0.258	NS

- Equal variances assumed

(AV = *A. variegatum*, AG = *A. gemma*, AC = *A. cohaerens*, AL = *A. lepidum*, BD = *B. decoloratus*, RhE = *Rh. evertsi evertsi*, NS = Not significant, * * * = Highly significant and * * = Significant)

From midland, Kokatie, 2289 and 2136 adult ixodid tick species collected from half-body regions of 138 cattle in wet and 138 cattle in dry periods. Then eight tick species were identified (shown on Figure 4). The most abundant tick species during wet period at this study site was *B. decoloratus* (47.53%), and the least was *Rh. guilhoni* (1.05%). During dry period *B. decoloratus* (47.47%) was the most abundant tick species, and *Rh. muhsamae* (0.38%) was the least identified tick species.

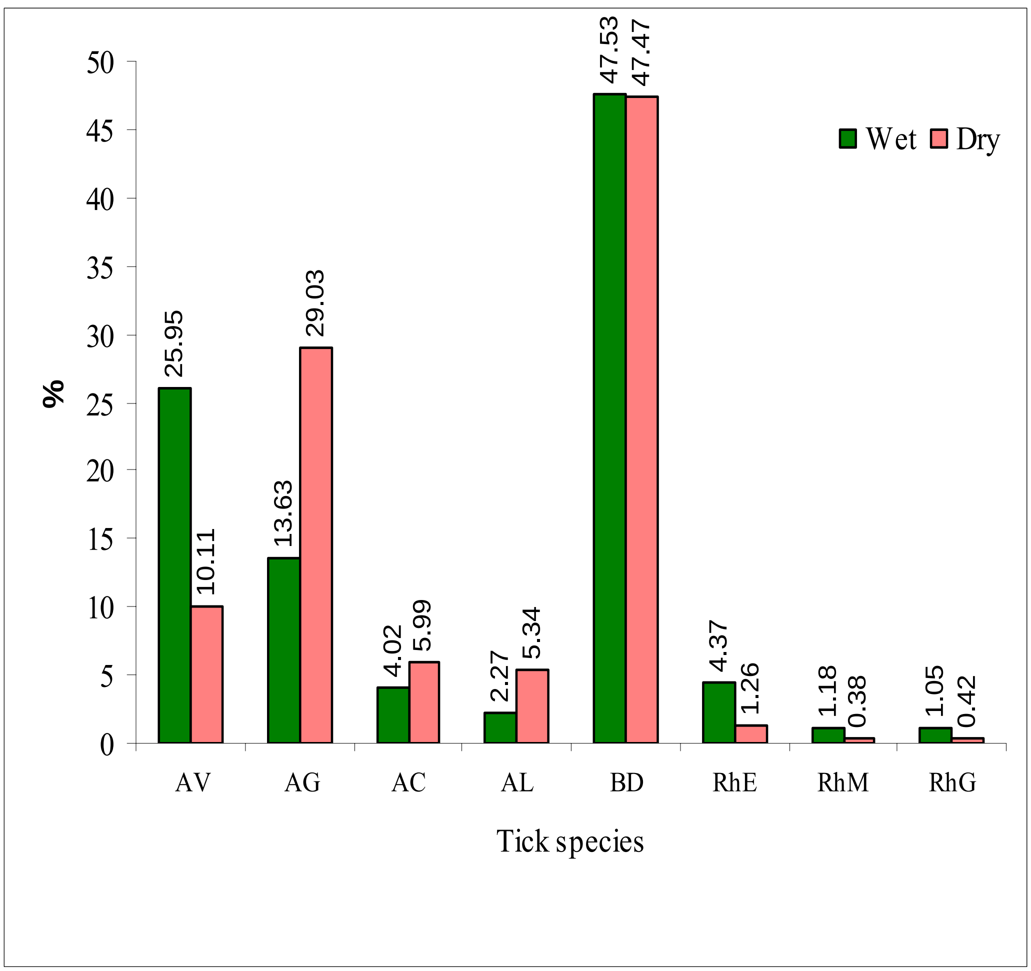


Figure 4. Tick species identified during wet and dry periods at midland, Kokatie.

The percentage of *A. variegatum* was higher during wet period than dry period, but for *A. gemma* the vice- versa was true (95% CI for mean3.130 - 5.478 and 1.195 - 1.936 for *A. variegatum* in wet and dry periods, while1.919 - 2.603 and 3.801 - 5.185 for *A. gemma* in wet and dry periods). The significance of seasonal variation of the major tick species at Kokatie shown on Table 3.

Table 3. Seasonal variation of the major tick species at midland tested by two-sample t test with equal variances

Tick spp.	Season	Mean	Std. Deviation	Std. Error	t - value	df	P > |t|	[95% Conf. Interval]	Significance
AV	Wet	4.304	6.975	0.594				3.130 - 5.478	
	Dry	1.565	2.201	0.187	4.3993	274	0.0000	1.195 - 1.936	* * *
AG	Wet	2.261	2.034	0.173				1.919 - 2.603	
	Dry	4.493	4.110	0.350	-5.7173	274	0.0000	3.801 - 5.185	* * *
AC	Wet	0.667	1.658	0.141				0.388 - 0.946	
	Dry	0.928	1.890	0.161	-1.2189	274	0.2239	0.609 - 1.246	NS
AL	Wet	0.377	1.062	0.090				0.198 - 0.556	
	Dry	0.826	2.032	0.173	-2.3018	274	0.0221	0.484 - 1.168	* *
BD	Wet	7.884	3.752	0.319				7.253 - 8.516	
	Dry	7.348	4.634	0.394	1.0566	274	0.2916	6.568 - 8.128	NS
RhE	Wet	0.725	1.355	0.115				0.497 – 0.953	
	Dry	0.196	0.638	0.054	4.1495	274	0.0000	0.088 – 0.303	* * *

- Equal variances assumed

(AV = *A. variegatum*, AG = *A. gemma*, AC = *A. cohaerens*, AL = *A. lepidum*, BD = *B.decoloratus*, RhE = *Rh. evertsi evertsi* NS = Not significant,
* * * = Highly significant and * * = Significant)

From lowland, Bombie, 1856 and 2238 adult ixodid tick species collected from half-body regions of 138 cattle in wet and dry periods. Then eleven species of ticks were identified from this collection. The most abundant tick species during wet period at Bombie was *B. decoloratus* (30.71%), and the least was *Rh. muhsamae* (1.05%). During dry period *B. decoloratus* (45.40%) was the most abundant tick species, and *Rh. guilhoni* (0.72%) was the least identified tick species. The other identified tick species and their order of abundance in wet and dry periods can be observed from Figure 5.

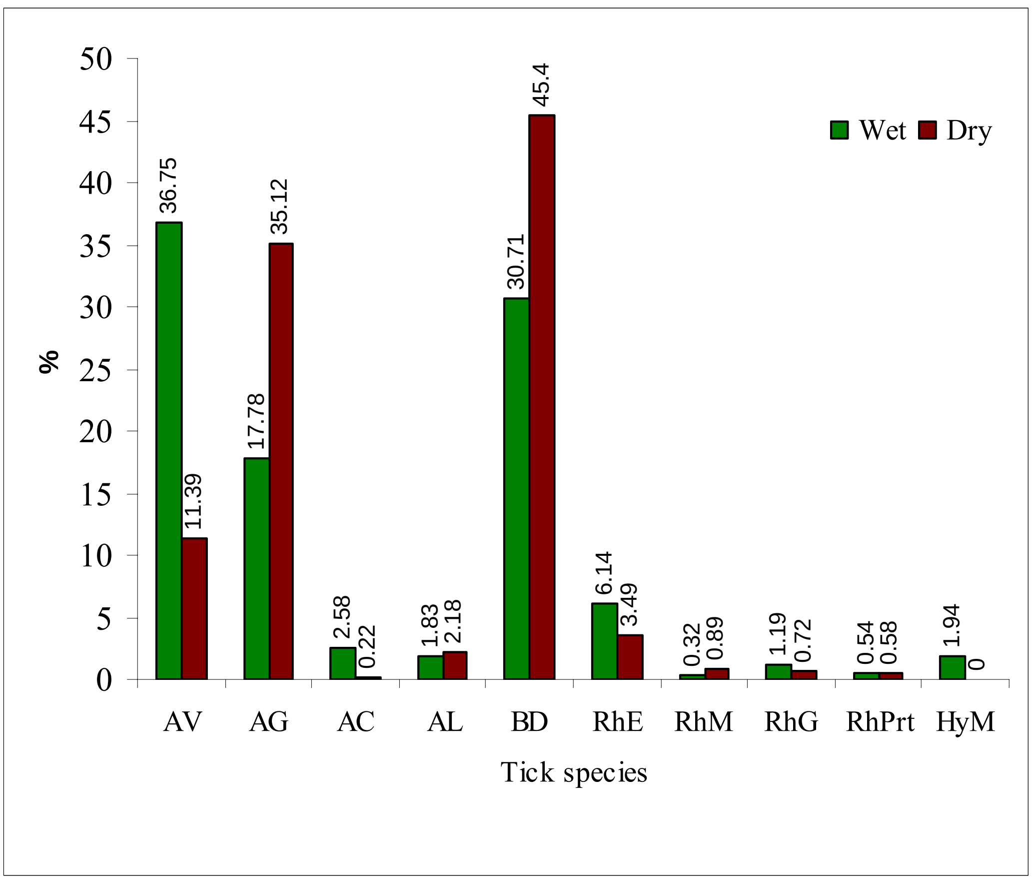


Figure 5. Tick species identified during wet and dry periods from lowland, Bombie.

During wet period there was higher distribution of *A variegatum* and *A. cohaerens* than the dry period, which has statistically significant variation (P = 0.0000 and P = 0.0009). But for *A. gemma* distribution the opposite is true (P = 0.000). The analysis of seasonal variation of the major tick species at Bombie shown on Table 4.

Rh. pravus was collected from this study site only during wet period, which accounts for 0.22% of this period collection. Similarly *Hy. m. rufipes*, which accounts 1.94% of this period collection, was collected during wet period only.

Table 4. Seasonal variation of the major tick species at lowland tested by two-sample t-test with equal variances

Tick spp.	Season	Mean	Std. Deviation	Std. Error	t - value	df	P > |t|	[95% Conf. Interval]	Significance
AV	Wet	4.942	3.743	0.319				4.312 - 5.572	
	Dry	1.848	2.663	0.227	7.9122	274	0.0000	1.400 - 2.296	* * *
AG	Wet	2.406	3.616	0.308				1.797 - 3.014	
	Dry	5.696	4.541	0.387	-6.6576	274	0.0000	4.931 - 6.460	* * *
AC	Wet	0.333	1.006	0.086				0.164 - 0.503	
	Dry	0.036	0.254	0.022	3.3638	274	0.0009	0.006 - 0.079	* * *
AL	Wet	0.246	0.878	0.075				0.099 - 0.394	
	Dry	0.355	0.980	0.083	-0.9704	274	0.3327	0.190 - 0.520	NS
BD	Wet	4.130	1.936	0.165				3.804 - 4.456	
	Dry	7.362	3.566	0.304	-9.3569	274	0.0000	6.762 - 7.963	* * *
RhE	Wet	0.826	1.255	0.107				0.615 - 1.037	
	Dry	0.565	1.127	0.096	1.8169	274	0.0703	0.376 - 0.755	NS

- Equal variances assumed

(AV = *A. variegatum*, AG = *A. gemma*, AC = *A. cohaerens*, AL = *A. lepidum*, BD = *B.decoloratus*, RhE = *Rh. evertsi evertsi*, NS = Not significant, * * * = Highly significant and * * = Significant)

A. variegatum, *A. gemma* and *A. cohaerens* mean distributions have statistically significant variation both seasonally (t = 10.2719, P = 0.000; t = -7.7583, P = 0.000 and t = 4.3619, P = 0.000 respectively at α = 0.005 and df =826) and agro-ecologically (F= 11.993, P = 0.000; F= 22.332, P = 0.000 and F= 13.183, P = 0.000 respectively at α= 0.05 and df = 2). But there was no significant mean distribution variation of *A. cohaerens* between highland and midland (P = 0.912, 95% CI 0.630 – 0.993 for highland and 0.615 – 0.972 for midland). For mean distribution variation between the three agro-ecologies pairwise comparison for the most common tick species shown on Annex 1. The wet period proportion of A. *variegatum* 20.82% at highland, 25.95% at midland and 36.75% at lowland were decreased to 4.20%, 10.11% and 11.39% respectively in dry period. Though the wet period percentage of *A. gemma* 12.02% at highland, 13.63% at midland and 17.78% at lowland were increased to 17.87%, 29.03% and 35.12% respectively during dry period.

There was an overall *B. decoloratus* mean distribution variation agro-ecologically (F= 5.743, P = 0.000 at α = 0.05 and df = 2), but no significant variation was observed between highland and midland (P = 0.610, 95% CI 7.342 – 8.209 and 7.182 – 8.049 respectively). In all the three agro-ecological zones as a whole *B. decoloratus* mean distribution was significantly varied seasonally (t = -5.3937, P = 0.000 at α = 0.05 and df = 826). This study showed that the mean distribution of *Rh. evertsi evertsi* was agro-ecologically significantly varied statistically (F= 18.018, P = 0.000 at α = 0.05 and df = 2). Its distribution was higher during wet period (95% CI 0.504 – 0.743 at α = 0.05) than dry period (95% CI 0.222 – 0.386 at α = 0.05). Since sufficient number of other species were not collected, it was impossible to perform statistical analysis. But their percentage/proportion of collection showed on Figure 3, 4 and 5 for each of the collection agro-ecological zones: highland, midland and lowland respectively.

4.1.2 Prevalence of tick species

Through the study conducted on 138 cattle from each agro-ecological zone the prevalence of adult tick species were analyzed and the result shown on table 5. The prevalence of each species was determined based on the number of cattle infested by the respective species. The prevalence of the least common tick species was: at midland in wet period *Rh. praetextatus* 2.9% and *Hy. m. rufipes* 6.5%; at lowland in wet period *Rh. pravus* 1.4%, *Rh. praetextatus* 4.3% and *Hy. m. rufipes* 5.8%; but in the area during dry period *Rh. praetextatus* 3.6%. The average number of the adults per half-body regions of cattle range1.7-2.6 for *Rh. praetextatus*, 0-1.4 for *Rh. pravus*, and 3.6-5.8 for *Hy. m. rufipes* in wet and dry period respectively when all the study areas taken together.

The average number of adult. *A. variegatum* per half body regions ranges 5.0-5.5 and 2.4-4.0 during wet and dry periods respectively. Similarly during wet period the average number of adults per half- body regions was: *A. gemma* 3.6-5.3, *A. cohaerens* 2.7-4.1, *A. lepidum* 2.4-2.8, *B. decoloratus* 4.1-7.9, *Rh. e. evertsi* 2.5-2.6, *Rh. muhsamae* 1.5-1.7 and *Rh. guilhoni* 2.2-2.8. During dry period the ranges were: 4.7-6.5, 2.3-5.2, 2.7-3.9, 7.3-8.6, 2.1-2.4, 2.0-2.7 and 0-2.3 for *A. gemma*, *A. cohaerens*, *A. lepidum*, *B. decoloratus*, *Rh. e. evertsi*, *Rh. muhsamae* and *Rh. guilhoni* respectively.

Table 5. Prevalence association between infestation rate during wet and dry periods, and agro-ecology (at α= 0.05)

Agro-ecology	Season		AV	AG	AC	AL	BD	RhE	RhM	RhG
Highland (N= 138)	Wet	No of positive	77	56	51	24	138	17	18	-
		percentage	55.8%	40.6%	37.0%	17.4%	100%	12.3%	13.0%	-
	Dry	No of positive	28	62	6	13	138	9	2	-
		percentage	20.3%	44.9%	4.3%	9.4%	100%	6.5%	1.4%	-
	X^2		36.906	0.533	44.773	3.777	NC	2.718	13.800	-
	P		0.000 * *	0.465	0.000 * *	0.052	NC	0.099	0.000**	-
Midland (N= 138)	Wet	No of positive	118	87	28	22	138	38	18	11
		percentage	85.5%	63.0%	20.3%	15.9%	100%	27.5%	13.0%	8.0%
	Dry	No of positive	62	96	41	29	138	13	3	4
		percentage	44.9%	69.6%	29.7%	21.0%	100%	9.4%	2.2%	2.9%
	X^2		50.089	1.314	3.266	1.179	NC	15.033	11.597	3.454
	P		0.000**	0.252	0.071	0.278	NC	0.000**	0.001**	0.063
Lowland (N= 138)	Wet	No of positive	127	64	17	12	138	466	4	8
		percentage	29.0%	46.4%	12.3%	8.7%	100%	33.3%	2.9%	5.8%
	Dry	No of positive	63	124	3	18	138	32	8	7
		percentage	45.7%	89.9%	2.2%	13.0%	100%	23.2%	5.8%	5.1%
	X^2		69.186	60.058	10.566	1.346	NC	3.503	1.394	0.070
	P		0.000**	0.000**	0.001**	0.246	NC	0.061	0.238	0.791

NB. - AV= *A. variegatum*, AG= *A. gemma*, AC= *A. cohaerens*, AL= *A. lepidum*, BD= *B. decoloratus*, RhE= *Rh. e. evertsi*, RhM= *Rh. muhsamae* and RhG= *Rh. guilhoni*.

- N= Number of animals examined NC= Not computed because it is a constant.

- ** = Significant

When all the study areas considered together the infestation rate of *A. variegatum*, *A. cohaerens Rh. e. evertsi* and *Rh. muhsamae* were significantly higher during wet period than the dry period (X^2 =141.038, P= 0.000; X^2 =17.596, P=0.000; X^2 =17.534, P=0.000 and X^2 =14.695, P=0.000 respectively). But the infestation rate of *A. gemma* was significantly higher during dry period than wet period (X^2 =28.096, P=0.000).

Agro-ecology has an overall effect on the infestation rate variation for *A. variegatum*, *A. gemma*, *A. cohaerens*, and *Rh. muhsamae*, which were statistically significant (X^2=20.57, P=0.0000; X^2=21.47, P=0.0000; X^2=29.67, P=0.0000 and X^2=13.22, P=0.0013 respectively). But there was no significant variation of infestation rate agro-ecologically for *A. lepidum* and *Rh. e. evertsi* (X^2=5.64, P=0.0597 and X^2=4.12, P=0.1276 respectively).

4.1.3 Attachment sites

Each species of tick consistently favoured various body regions of cattle, but the preferences were stronger in some species than others. The observed proportion of tick species attachment sites during this study was summarized and shown on table 6. The most preferred predilection sites of all *Amblyomma* species identified during this study were scrotum | udder, brisket, inside part of the legs and belly in decreasing order of preference. *B. decoloratus* preferred attachment sites in decreasing order were dewlap, belly, leg and head. During this study periods identified *Rhipicephalus* species were found primarily attached to anogenital regions and secondarily on head.

Table 6. Summary of the attachment sites percentages of the most common tick species in the study areas.

Tick species	*Body regions*							
	Head	Dewlap	Brisket	Belly + back	Leg	Scrotum/ Udder	Tail	Anogenital
A. gemma	3.29	4.68	22.94	11.41	19.92	35.51	0.31	1.93
A. variegatum	3.73	3.35	25.12	12.45	12.23	42.39	0.62	0.13
A. cohaerens	0.61	4.65	26.87	9.49	10.10	46.87	-	1.41
A. lepidum	1.42	4.83	15.06	2.84	17.61	54.83	0.57	2.84
B. decoloratus	7.70	52.52	5.42	12.98	10.40	6.17	3.87	0.94
Rh. e. evertsi	4.95	-	-	-	-	0.26	-	94.79
Rh. guilhoni	23.66	-	-	-	-	-	-	65.59
Rh. muhsamae	25.26	-	6.45	-	-	-	4.30	74.74

4.1.4 Sex ratios

The sex ratio, male/female, seen in this study for *Amblyomma* species and *Rhipicephalus* species in all the three agro-ecological zones were greater than one, but for *B. decoloratus* it was less than one. This holds true both in wet and dry periods.

Table 7. Sex ratio of the major tick species in the three agro-ecological zones during wet and dry periods.

Name of tick species	Highland		Midland		Lowland		Overall sex ratio
	Wet period	Dry period	Wet period	Dry period	Wet period	Dry period	
A. gemma	1.6:1	1.9:1	2.2:1	2.4:	1.7:1	1.7:1	1.9:1
A. variegatum	1.8:1	1.8:1	1.4:1	2.3:1	1.6:1	1.6:1	1.7:1
A. cohaerens	1.4:1	6:1	2.8:1	1.9:1	1.1:1	4:1	1.9:1
A. lepidum	2.4:1	3.4:1	2.7:1	3.4:1	2.2:1	3.1:1	2.9:1
B. decoloratus	1:1.5	1:1.6	1:1.3	1:1.9	1:1.3	1:1.5	1:1.5
Rh. e. evertsi	1.8:1	1.1:1	2.3:1	4.5:1	2.4:1	1.9:1	2.1:1
Rh. guilhoni	2.7:1	-	1.7:1	3.5:1	4.5:1	3.0:1	2.7:1
Rh. muhsamae	1.7:1	1.0:3	2.0:1	3.0:1	2.0:1	3.0:	2.1:1

4.2 Tick burden

The total tick burdens of sixteen cattle from each agro-ecological zone were counted on half-body regions from August to April. The minimum, maximum and mean half-body regions burden of wet and dry periods were shown on Table 8.

Table 8. Half-body regions mean total tick burden of the three agro-ecologies.

Agro-ecology	Breed	Season	Minimum count	Maximum count	Mean count	Std. deviation
		Wet	17	300	90.75	59.72
Highland	Indigenous	Dry	8	137	44.11	24.93
		Wet	36	186	106.95	38.99
Midland	Indigenous	Dry	12	130	43.50	22.46
	Holstein	Wet	100	444	260.50	89.14
Midland	cross	Dry	33	358	142.84	75.41
		Wet	11	203	84.89	45.90
Lowland	Indigenous	Dry	12	170	46.45	33.07

4.2.1 Tick burden of local indigenous cattle

The highest half-body regions total tick burdens were recorded in wet months (August, September and October) of the study periods as the change pattern shown on plots of Figure 7. The mean wet and dry periods half-body regions total tick burden of local cattle at the three agro-ecological (highland, midland and lowland) zones shown on Figure 6.

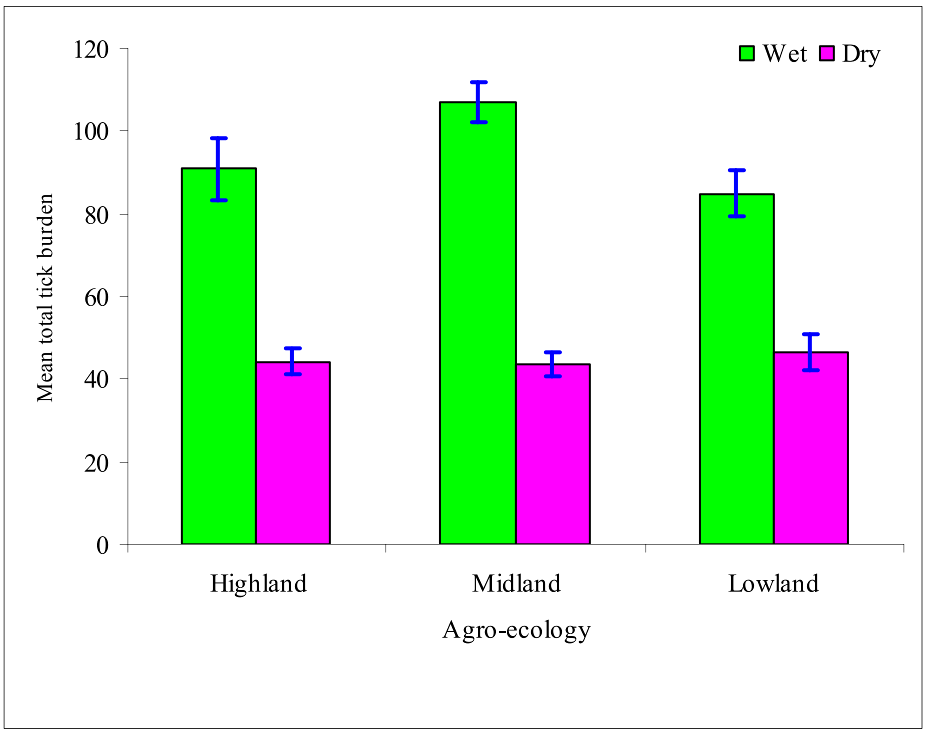


Figure 6. Mean wet and dry periods indigenous half-body regions total tick burden.

The analysis of the monthly half-body regions total tick burden by repeated measure of adjusted univariate approach of Greenhouse-Geisser adjustment showed statistically significant variation within agro-ecology (F= 185.843, P = 0.000 and Partial η squared = 0.805). As shown on Figure 7 the mean Log_{10} (X + 1) monthly half-body regions total tick burden of August not significantly varied from the monthly total tick burden of September and October (P = 0.923 and P = 0.739 respectively; 95% CI for August 1.969-2.082, September 1.976-2.071 and October 1.978-2.057). Also there was no significant variation between January and February (P= 0.252, 95% CI 1.617-1.701 and 1.400-1.480 respectively). There was also significant variation within the agro-ecological zones in the different months (F= 3.561, P= 0.037 at α= 0.05). The burden variation was also significantly effected by interaction of month and agro-ecology (F= 7.663, P= 0.000 and Partial η squared= 0.341).

Table 9. Mean monthly total tick burden repeated measure analysis result of indigenous cattle between agro-ecology

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	1175.413	1	1175.413	16803.747	0.000
Agro-ecology	0.498	2	0.249	3.561	0.037
Error	3.148	45	0.070		

(Repeated measure of adjusted univariate approach test)

The pattern of the changes of the mean Log_{10} (X + 1) monthly total tick burden of indigenous in all the three agro-ecological zones (highland, midland and lowland) is shown on Figure 7.

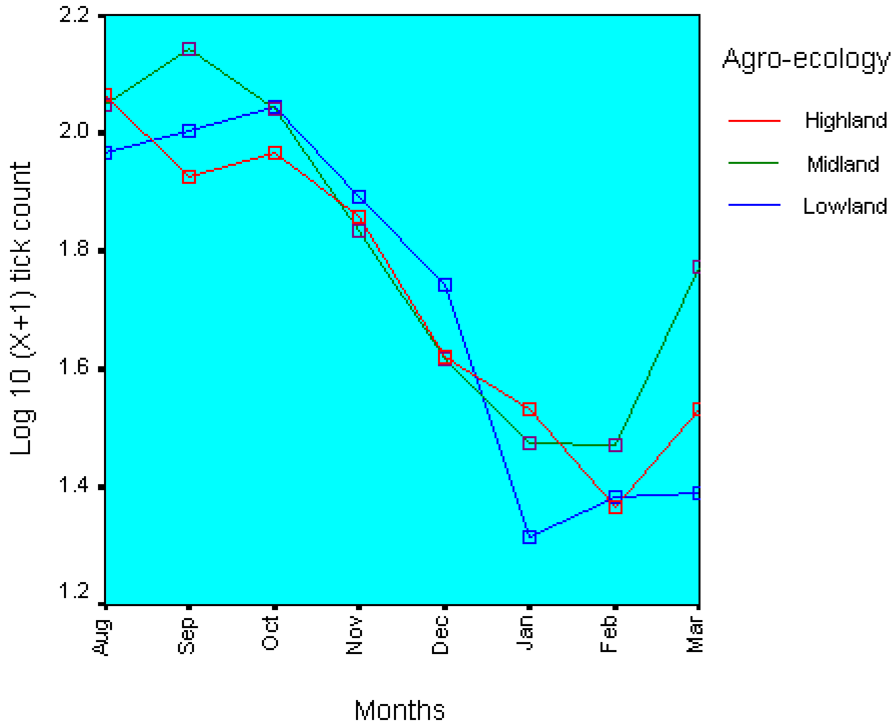


Figure 7. Mean monthly half-body total tick burden of indigenous cattle at the three Agro-ecological zones.

4.2.2 Tick burden of indigenous vs. Holstein cross in midland

The mean monthly half-body regions total tick burden of Holstein cross was higher through out the study periods than the indigenous breed at midland, Kokatie. The mean wet and dry periods half-body regions total tick burden shown on Figure 8.

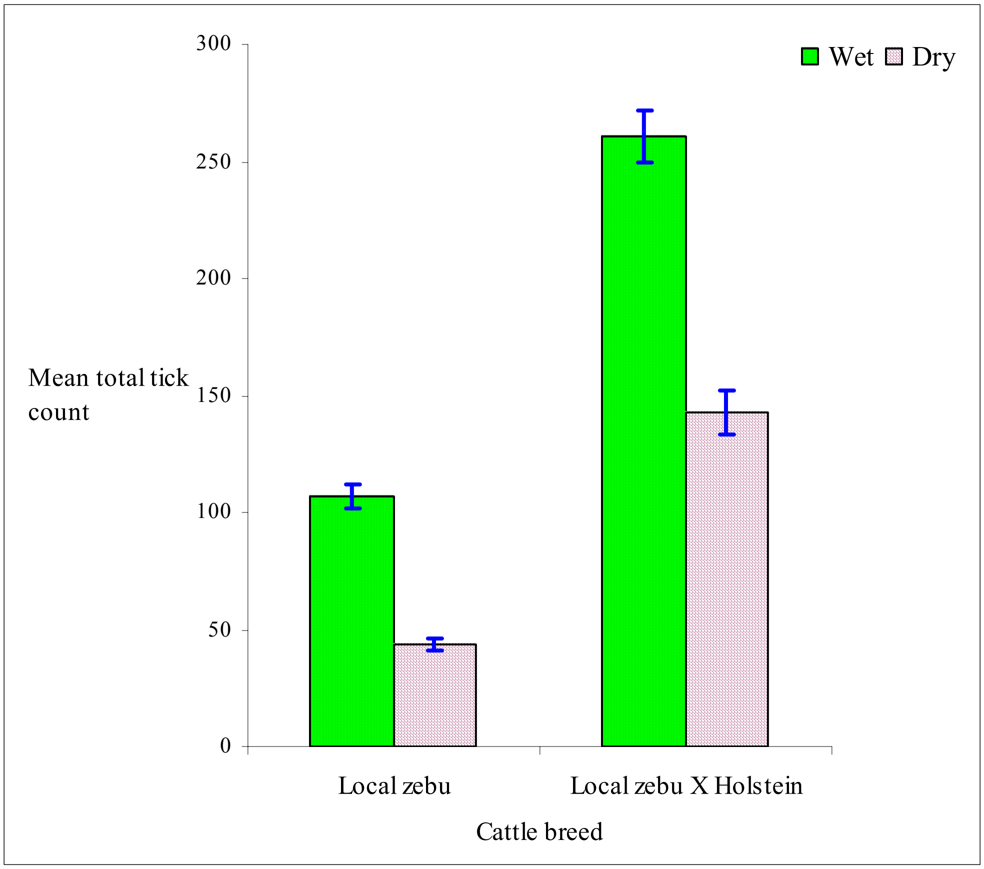


Figure 8. Mean wet and dry periods half-body regions total tick burden of indigenous and Holstein cross.

The mean monthly half-body regions total tick burdens of the two breeds, indigenous and Holstein cross, at the midland by adjusted univariate approach, Greenhouse Geisser adjustment method, were significantly varied (F= 370.610, P= 0.000, Partial η squared= 0.925; 95% CI 1.766-1.833 for indigenous and 2.209-2.275 for Holstein cross at α= 0.05). Also within the breed there was significant mean monthly half-body regions total tick burden variation of each breed, due to the interaction of breeds with months (F= 4.585, P= 0.001 and Partial η squared = 0.132 at α= 0.05).

Table 10 Mean monthly total tick burden repeated measure of adjusted univariate test result of within-subjects (in each breed and month).

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Month * Breed	Sphericity Assumed	0.485	7	0.069	4.585	0.000
	Greenhouse-Geisser	0.485	4.257	0.114	4.585	0.001
Error (Month)	Greenhouse-Geisser	3.176	127.704	0.025		

- Within subject design: Month - Half-body regions analysis

The pattern of the changes of the mean Log $_{10}$ (X + 1) half-body regions monthly total tick burden of indigenous and Holstein cross at midland, Kokatie, is shown on Figure 9.

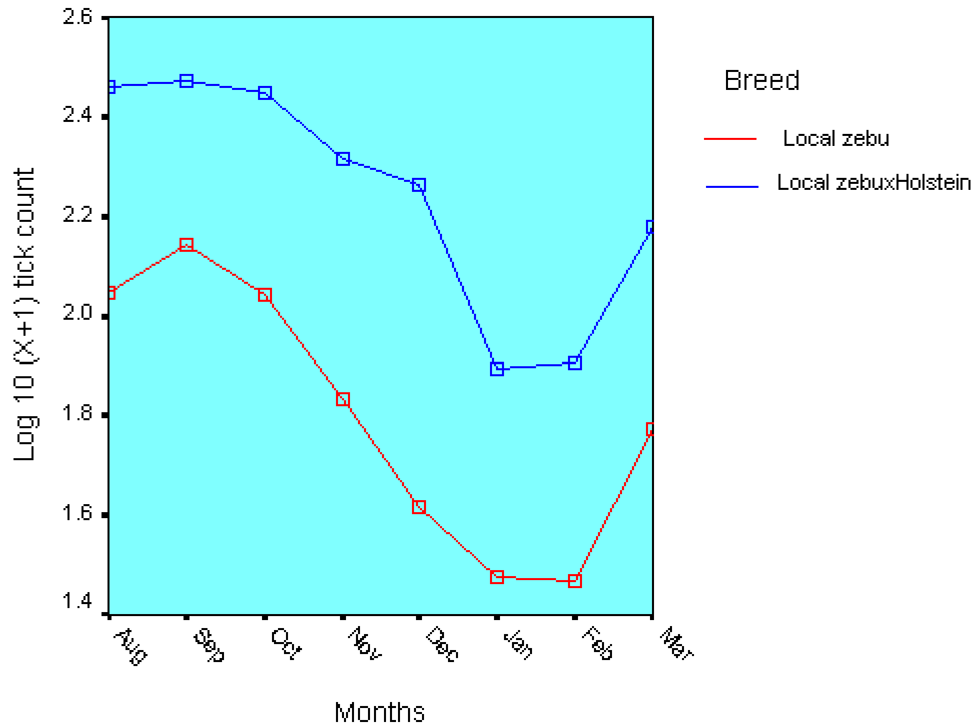


Figure 9. Mean monthly half-body regions total tick burden of indigenous and Holstein cross at Kokatie, midland.

Table 11. Mean monthly total tick burden of indigenous and Holstein cross at Kokatie, midland.

Breed	Months	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Local zebu	August	2.047(a)	0.030	1.986	2.107
	September	2.142(a)	0.019	2.102	2.181
	October	2.041(a)	0.030	1.980	2.102
	November	1.833(a)	0.033	1.767	1.900
	December	1.616(a)	0.037	1.540	1.691
	January	1.476(a)	0.039	1.397	1.555
	February	1.470(a)	0.040	1.389	1.551
	March	1.774(a)	0.033	1.706	1.841
Local zebu X Holstein	August	2.459(a)	0.030	2.399	2.520
	September	2.472(a)	0.019	2.433	2.511
	October	2.446(a)	0.030	2.385	2.507
	November	2.314(a)	0.033	2.248	2.381
	December	2.264(a)	0.037	2.189	2.340
	January	1.896(a)	0.039	1.817	1.975
	February	1.907(a)	0.040	1.826	1.988
	March	2.179(a)	0.033	2.111	2.247

-Log $_{10}$ (X + 1) transformed half-body regions data.

5. DISCUSSION

The lack of available information of the distribution, abundance, prevalence and seasonal dynamics of ticks makes it difficult to determine their impact. Hence presence of such information enables to asses as much as possible the losses encountered due to tick, and TBD. Then after to devise an economical and effective control system. The seasonal dynamics of ticks is the main factor that exerts a major quantitative influence on the transmission dynamics of TBD. Therefore, this study of cattle tick dynamics undertaken in Wolayta to provide this basic information.

5.1 Tick species identified

In this study a total of 12,182 ticks were collected from half-body regions of cattle from three agro-ecological zones of Wolayta, Southern Ethiopia. The eight most common tick species encountered in all the study areas were *B. decoloratus*, *A. variegatum*, *A. gemma*, *A. cohaerens*, *A. lepidum*, *Rh. evertsi evertsi*, *Rh. muhsamae* and *Rh. guilhoni*. The unrestricted cattle movement from area to area the fundamental factor for the presence of similar tick species almost in all agro-ecological zones.

B. decoloratus: It was the most abundant of all tick species both at Dalbo-Woganie, highland (46.92% and 73.35%) and Kokatie, midland (47.53% and 47.47%) during wet and dry periods respectively. This finding was in a general agreement with Naser (1985) and G/Michael (1993) reports from all Wolayta areas. Solomon *et al*. (2000) observed at Sebeta, western shoa, which is with similar altitude (2260 m above sea level) which was the most common and abundant tick species. At lowland, Bombie, this species was the second most abundant constituting 30.71% and 45.40% of the total ticks' collection during wet and dry periods. Solomon (1993) recorded similar abundance level at Abernossa, which is 1600 m above sea level. This species was reported to be widely distributed in the central Rift-Valley of Ethiopia (Pegram *et al*., 1981 and Dhuffera, 1997), which is part of Ethiopian lowland. *B. decoloratus* is one of the most important cattle tick in Ethiopia for its parasitic importance (Morel, 1980). According to Hoogstraal (1956) it was present at all altitude from sea level to high mountains, and can withstand both frost and high temperature except in desert areas. The outcome of this study agreed with idea in that it was the most distributed in all the agro-ecological zones of Wolayta. B. decoloratus present in the study areas throughout the study periods.

During this study periods taking into account all the study areas together *B. decoloratus* showed statistically significant mean distribution variation both seasonally ($t = -5.3937$, $P = 0.0000$ at $\alpha = 0.05$) and agro-ecologically ($F = 5.743$, $P = 0.003$ at $\alpha = 0.05$). Higher relative number of this species collected during dry period. The agro-ecological zones mean distribution difference observed between lowland, midland and highland (95% CI was 7.342 – 8.209 at highland, 7.182 – 8.049 at midland and 5.313 – 6.180 at lowland). According to de Castro (1994) in areas with bimodal rainfall, like Wolayta, female *B. decoloratus* is abundant from end of rainfall peak to the beginning of the next rainy season. Hence the finding of this study was in agreement with this observation in that the mean distribution of *B. decoloratus* was higher during dry period as compared to wet period collection (95% CI of 5.981 – 6.666 at wet period and 7.368 – 8.168 at dry period, $\alpha = 0.05$ and df = 826). The mean maximum and minimum temperature in dry time at

Soddo and Areka were27.44^{0}C/14.88^{0}C and 29.220C/16.56^{0}C respectively. The average humidity percentages of Soddo and Areka in dry period were 50.26% and 46.56%. These mean monthly humidity and temperature record of the study areas were conducive for *B. decoloratus* reproduction. This study finding also agreed with study conducted on Ogaden cattle at Alemaya Agriculture University campus by Bekele (2002). He reported that B. decoloratus peak number was observed in December, which was dry season for that area. The area receives a bimodal rainfall type and the average annual rainfall during the study period was 800mm; and the maximum and minimum annual temperature were 23.6^{0}C and 10.1^{0}C respectively. There was seasonal mean distribution difference in all agro-ecological zones except at midland (P = 0.0004 at highland, P = 0.2916 at midland and P = 0.0000 at lowland). This study finding at highland and lowland were different from Kaiser *et al.* (1988) who reported that there was no clear evident seasonal pattern with this species in Ijend, Burundi. Ijend area was characterized by maximum and minimum temperature of 19.8^{0}C and 14.3^{0}C respectively; and annual rainfall of 1549mm. Also Kaiser *et al.* (1991) observed no clear seasonal pattern of this species at northern Uganda. But the midland finding of this study agreed with these two reports, Kaiser *et al*. (1988) and Kaiser *et al*. (1991). Since the rainfall, humidity and temperature prevailing at midland (shown on table 1) is more suitable for this tick species, it is possible to get such situation in areas like Kokatie. Also Gashaw (2004) observed that when the monthly rainfall in excess of 250 mm there was reduction in *B. decoloratus* numbers and infestations. Otherwise the number and distribution of *B. decoloratus* will be higher in wet period. The basic reason for this difference could be possibly accounted to the variation in weather and agro-ecology. This species evolutive cycle is monophasic and exophilous (Morel, 1980). As observed form the meteorological data at

Soddo and Areka the humidity percentages prevailing in areas allow the development of *B. decoloratus*. Its relative abundance increases as one move from lowland to highland.

A. variegatum: This species was the second most abundant at highland (20.82%) and midland (25.95%), but it was the most abundant at lowland (36.75%) during wet period. *A. variegatum* level of abundance became decreased during dry period in all the study areas to 4.20%, 10.11% and 11.39% at highland, midland and lowland respectively. Naser (1985) and G/Michael (1993) reported that it was one of the most distributed tick species in Wolayta. In Ethiopia as a whole it is the most commonly found tick species (Bergeon and Balis, 1974 and Pegram *et al*., 1981). In this study *A. variegatum* showed significant mean distribution variation in the study areas as a whole both seasonally ($t = 10.2719$, $P = 0.000$ at $\alpha = 0.05$) and agro-ecologically ($F = 11.993$, $P = 0.000$ at $\alpha = 0.05$). Also the mean distribution in each agro-ecological zones was seasonally varied significantly ($t = 7.6371$, $P = 0.0000$ at highland; $t = 4.3993$, $P = 0.0000$ at midland; and $t = 7.9122$, $P = 0.0000$ at lowland). In all the study areas highest mean count were seen during wet period. This finding in agreement with that of Solomon *et al*. (2000) and Solomon (1993) observations at Sebeta and Abernossa respectively. They recorded highest counts of *A. variegatum* in July and April, which are the rainy months for the areas. Yohualashet *et al*. (1995) also observed the seasonal fluctuation of with a relative rise in numbers during the short and long rains at Adami-Tulu, Ethiopia. Bekele (2002) also reported that highest or peak of this species during wet period at Alemaya Agricultural University Campus. The life-cycle of this tick species mostly closely linked to rainfall. The adults were aroused by rain in the rainy months, by which time most had apparently found a host (Kaiser *et al*., 1988). In Ethiopia Pegram *et al*. (1981) observed that the on set of feeding activity of adult coincides with the start of wet season. From de Castro (1994) survey in western Ethiopia females *A. variegatum* were mostly present in rain time collections of tick species. Assefa (2004) reported the peak its occurrence in and just following the rainy season at Asella, and almost absent in dry period, which is February and early March, tick collections. Hoogstraal (1956) and Morel (1980) observed that *A. variegatum* population increase in numbers and remain high through the rainy season and decrease rapidly in the dry season. Its seasonal prevalence was peaked during the rainy season in traditionally managed N'Dama cattle in Gambia (Mattioli *et al*., 1997). The occurrence of adult *A. variegatum* in Malawi cattle herds that kept under traditional management systems almost restricted to the rain season (Lorenz *et al*., 1996). According to Petney *et al*. (1987) the adult stage of *A. variegatum* is abundant in high number during the rain season. But larvae and nymphs gradually become more numerous in the dry season (Hoogstraal, 1956 and Morel, 1980). That is mainly due to the activation of quiescent adult by rainfall. This mainly due to the exophilic nature of *A. variegatum*.

A. gemma: This species was the third most abundant in Wolayta as a whole. When one moves from high to lower altitude the proportion of *A. gemma* increased both during wet and dry periods. But during dry period its abundance increased and become the second most abundant species. This finding was agreed with that of Naser (1985) and G/Michael (1993) who was reporting it was the most abundant tick species next to *A. variegatum* in Wolayta in general. This study result showed that this species mean distribution was significantly varied seasonally when Wolayta as a whole is considered ($t = -7.7583$, $P = 0.0000$ at $\alpha = 0.05$). The seasonal mean distribution in each agro-ecology also varied significantly except at highland ($t = 6.6576$, $P = 0.0000$ at lowland; $t = -5.7173$, $P = 0.0000$ at midland and $t = -0.8962$, $P = 0.3709$ at highland).

Being *A. gemma* prefers arid and semi-arid habitat (Morel, 1980) its distribution is very low at highland, hence difficult to observe statistically significant variation at this agro-ecological zone. The highest mean distribution recorded during dry period (95% CI of 1.797 – 3.014 and 4.931 – 6.460 in wet and dry periods respectively at lowland; 1.919 – 2.603 and 3.801 – 5.183 in wet and dry periods respectively at midland; and 1.322 – 2.244 and 1.584 – 2.604 in wet and dry periods respectively). The result of this study agreed with Petney *et al*. (1987) who recorded of peak *A. gemma* abundance in the Kikumini areas, Kenya during driest months. *A. gemma* significantly varied also agro-ecologically (F = 22.332, P = 0.000) with the highest mean distribution at lowland (95% CI of 1.531 – 2.346, 2.969 – 3.784 and 3.643 – 4.458 at highland, midland and lowland respectively). This finding was agreed with observations of Pegram *et al*. (1981), Abdo (1986), Asrat (1987), Biru (1988),Yilma *et al*. (1995), Bekele (1996), Regassa (2001), Seyoum (2001) and Walker *et al*. (2003) who reported that the distribution of *A. gemma* was primarily lowland areas, characterized by low rainfall. According to Morel (1980) in Eastern Africa it was distributed more in areas receiving lesser rainfall with humid biotope. It is the African *Amblyomma*, which has the most xerophilous affinities (Morel, 1980).

A. cohaerens: It was the forth most abundant tick species in Wolayta. The mean distribution of *A. cohaerens* was significantly varied seasonally all when the study areas considered together (t = 4.3619, P = 0.0000), which was highest during wet period (95% CI of 0.656 – 1.025 and 0.238 – 0.472 during wet and dry periods respectively). Except at the midland there was significant seasonal variation at highland and lowland (t = 3.3638, P = 0.0009 at highland; t = -1.2189, P = 0.2239 at midland and t = 6.3934, P = 0.0000 at lowland). This result was similar to the finding of Morel (1980) who reported that the distribution of *A. cohaerens* corresponds on the highlands with short or insignificant dry period. Also de Castro (1994) collected highest adult females during the rainfall peak and following the peak rainfall in western Ethiopia. But he collected nymphs mostly between January and April, just before the rainfall peak. Pegram *et al*. (1981) from western Ethiopia, Haile (1987) from previous Illubabor, Mekuria (1987) from Nekemte Awraja, Belay (2004) from Mizan Teferi and Getachew (2004) from Jimma area reported the widespread ness of this species in western humid and/or highland of Ethiopia. Also in eastern highland, Alemaya, Ethiopia it was the most top abundant species and showed a abundance in rain period (Bekele, 2002). Assefa (2004) reported peak *A. cohaerens* in rainy and just following the rainy season at Asella, and insignificant numbers collected in February and early March, which the dry periods. There was significant variation between the study areas (F = 13.183, and P = 0.000). The mean difference was significant between highland and lowland, midland and lowland; but there was no difference between highland and midland (LSD = 0.000, LSD = 0.000 and LSD = 0,912 respectively). The reason for its abundance most in humid, and high- and midland areas could be due to its hygrophilic nature. According to Morel (1980) this species distribution coincides to annual rainfall almost always over 1,000mm, on the highland with short or insignificant dry period.

A. lepidum: During this study no seasonal, and agro-ecological variation observed (P = 0.2222 and P = 0.0860 respectively). Though its proportion was relatively higher during dry period, it was collected from all agro-ecological zones both in dry and wet periods. As mentioned by Morel (1980) this species is common but not abundant, which was also the finding of this study. In Ethiopia it occurs mainly in semi-arid and arid areas (Pegram *et al*., 1981). Hoogstraal (1956) and Pegram *et al*. (1981) reported that this species was most prevalent in drier habitats.

Therefore, being *A. lepidum* and *A. gemma* are ticks of arid and semi-arid areas; undoubtedly the two species should be more abundant in the dry period of the year. These characteristics make it the second most xerophilous African species of *Amblyomma*, after *A. gemma* (Morel, 1980).

Rh. evertsi evertsi: This species was the sixth common and abundant constituting 2.15%, 4.37% and 6.14% of highland, midland and lowland wet period collections respectively. Also 1.3%, 1.26% and 3.49% dry period collection of the respective agro-ecological zones. There was an overall seasonal variation when all the agro-ecological zones taken together (t = 4.3258, P = 0.0000).This seasonal variation was seen mainly at Kokatie, midland (t = 4.1495, P= 0.0000) with highest collection of adult this species in wet period (95% CI 0.497 – 0.953 and 0.088 – 0.303 during wet and dry periods respectively). This result basically with observation of Kaiser *et al*. (1991) who showed that all stages of Rh. *evertsi evertsi* were less active during dry season. In fact according to Pegram *et al*. (1981) and de Castro (1994) it appears to occupy a wide range of climatic and ecological conditions with rain most of the year, and occur throughout the year; but never numerous. Bekele (2002) reported that this species had not showed specific preference for a particular environment.

During this study period collections of the other tick species were too few to suggest their seasonal and agro-ecological patterns. They were *Rh. muhsamae, Rh. guilhoni, Rh. praetextatus* and *Hy. marginatum rufipes*. Their proportions were shown on Figure 3 to 5.

5.1.1 Attachment sites

Ticks shared the surfaces of their hosts remarkably well with each species having a preference for a different zone in an apparent evolutionary adaptation to reduce competition (Kaiser *et al*., 1982). The result of this showed that the predilection sites of ticks over the body of cattle was in generally similar to that observed by Kaiser *et al*. (1982) in southern Uganda, Kaiser *et al*. (1991) in northern Uganda, Howell *et al*. (1978) in South Africa, and Matthee *et al*. (1997) on impala at Letaba ranch, South Africa. The four most top predilection sites seen during this study for *B. decoloratus* were dewlap, belly and back, leg and head in decreasing order of preference. According to Howell *et al*. (1978) in heavy infestation B. decoloratus can be found any where on the body of cattle. During this study *A. variegatum*, *A. gemma*, *A. cohaerens* and *A. lepidum* found mainly attached to scrotum/udder, brisket and inside part of legs. Favourite attachment sites described for *A. variegatum*, *A. gemma* and *A. lepidum* are brisket, ventral surface of cattle, flanks, sternum, udder/scrotum lower dewlap (Hoogstraal, 1956; Howell *et al*., 1978 and Okello-Onen *et al*., 1999[a]). All *Rhipicephalus species* (*Rh. e. evertsi*, *Rh. muhsamae*, *Rh. praetextatus* and *Rh. pravus*) were found primarily attached to anal region and then few of them on ear. The attachment site observed during this study was shown on table 6. There was no seasonal agro-ecological difference of preferred attachment sites.

5.1.2 Sex ratio

Higher male to female sex ratio were observed for *A. variegatum*, A. *gemma*, A. *cohaerens*, *A. lepidum* and *Rhipicephalus species*. But for *B. decoloratus* the sex ratio skewed towards females in all the study areas of Wolayta. The result of this study agreed with the finding of Kaiser *et al*. (1982) in southern Uganda, Kaiser *et al*. (1991) in northern Uganda, Solomon *et al*. (1998) at

Didytuyura, Solomon *et al*. (2000) at Sebeta and Belay (2004) in and around Mizan Teferi. Dioli *et al*. (2001) reported male outnumbered female in study conducted on one humped camel. In southern Uganda Kaiser *et al*. (1982) found 1.4 – 2.3 male/female and 1.1 – 2.3 male/female ratios for *A. variegatum* and *Rh. e. evertsi* respectively. The same person in northern Uganda in 1991 reported 2.5 male/female and 3.0 male/female ratios for *A. variegatum* and *Rh. e. evertsi* respectively. Getachew (2004) reported 2.3:1, 6.2:1, 2.1:1, 3.2:1 and 0.06:1 male to female sex ratios for *A. cohaerens*, *A. variegatum*, *A. gemma Rh. e. evertsi* and *B. decoloratus* respectively in Jimma areas. The sex ratios result of this study was presented on table 7. Generally the male should be outnumbered the females due to the fact that females once fully engorged drop of the host and continue the process of ovipositing. But the males tend to remain on the host for several months and continue feeding and mating with other females (Solomon *et al*., 1998 and Mekonnen *et al*., 2001). Host grooming easily remove semi-engorged or engorged females as compared to males (Solomon *et al*. 1998).Lower number males *B. decoloratus* was observed than females during this study probably due to its very small size the male can be missed during sampling. The livestock owner's were not willing to shave their animals while sampling because of the cultural viewpoint prevailing in the area. This was also one of the contributory factors for missing males of *B. decoloratus*.

5.1.3 Prevalence

From this study result during an increment by the relative number of specific tick species the infestation rate of that species also increased. Tick species adapted to dry areas showed significant seasonal prevalence variation with their respective most preferred habitats. From this study as an example *A. gemma* can be taken, which showed significant seasonal variation commonly at lowland. On the other hand *A. cohaerens* showed significant seasonal variation at highland, which is its most preferred habitat. The average number of adult tick species per cattle found during this study was in agreement with Getachew (2004) who reported that 4.3, 12, 5.7, and 4.7 for *A. variegatum*, *A. gemma*, *B. decoloratus* and *Rh. evertsi evertsi*.

5.2 Total tick burden result of indigenous

The highest total tick burden was recorded in wet months (August, September and October), which gradually decreasing to the lowest infestation recorded in dry months (December, January and February) during this study. The minimum and maximum total tick burden observed on half-body regions of indigenous was 8 at highland and 300 at highland in February and August respectively. The finding of this study agreed with that of Solomon *et al.* (2000) who recorded highest total tick burden on cattle at Sebeta in June, which coincides with the early rainy season. Bekele (2002) also reported that highest total tick burden during wet period and lowest in December, which is middle of the dry season at Alemaya Agricultural University Campus. According to Dioli *et al.* (2001) observation on one-humped camel in Kenya and Southern Ethiopia the total tick load per half-body regions was higher in the wet season. This is mainly reflecting the increased reproductive rates of many species of ticks during the wet season. On other hand dryness affects the reproduction rate of tick, therefore, most tick undergo diapause in dry season to survive harsh time of the year. During dry period ticks unable to get sufficient vegetation and/or grasses that enable them to quest and wait for hosts. Reduction of the vegetation cover through heavy grazing due to shortage of grazing land will also make environmental conditions less favourable, reducing the number of ticks (de Castro, 1997a). In area like Wolayta where there is shortage of grazing land and regular ploughing of most of the lands (Wolayta Zone Rural Development Department basic data 2003) undoubtedly tend to reduce tick community by controlling movements of animals. Survey conducted in Queens Land showed that in areas where cropping and cattle production practiced as a sideline activity, it provides opportunity for producers to rotate cattle around pastures (Elder *et al.*, 1980). According to Minjauw and de Castro (2000) following heavy infestation heavy immunological response by the host will develop, and this might reduce/limit the next host infestation. This immunological response host play great role during early dry period, which then supported by the effect dry environmental conditions that impose ticks reproduction. The availability of nutrition extremely decline starting from mid-dry period to the level of total absence. During this time the immunity of the host starts to wane. Further the beginning of rain become more favourable for ticks' reproduction (Sutherst, 1987[b]). Therefore, falling of host immunity level followed by increased population of ticks, which result higher tick challenge in wet period. Hence in areas like Wolayta where there is short rainy time, it is characterized by high level of infestations.

5.3 Breed resistance for ticks

The breeds compared during this study were indigenous and Holstein cross at midland of the study area. This study revealed that there was significant variation of tick burden difference through the study periods between these two breeds ($F = 370.610$, $P = 0.000$ at $\alpha = 0.05$). The confidence interval of the mean monthly $\text{Log}_{10}(X+1)$ variation can be observed form table 7. The mean difference between the two breeds was statistically significant ($P = 0.000$ and 95% CI for mean difference 0.396-0.489). This result of this study finding agreed with Ali and de Castro (1993) who reported that Horro breed carried fewer total tick burdens than Horro X Holstein. Similarly Yohualashet *et al.* (1995), Solomon and Kaaya (1996), Aragaw (1994) reported better control of tick burdens in the local indigenous zebu than Holstein cross. According to Solomon and Kaaya (1998) observation *A. variegatum* and *B. decoloratus* fed on Boran X Holstein cattle survived longer than those fed on the indigenous Arssi and Boran breed. These breeds harboured less *A. cohaerens*, *B. decoloratus*, *Rh. praetextatus* and *Hy. marginatum rufipes* ticks than their crosses with Holstein (Solomon and Kaaya, 1996). From the observation of Solomon and Kaaya (1996) at Abernossa ranch local Arssi breed was the highest tick resistant, which was followed by the Boran breed, but Boran X Holstein was the least resistant. Moran *et al.* (1996) assessed host resistance to ticks on cross-bred cattle in Burundi and found that pure Ankole cattle were more resistant than Ankole X Holstein.

Therefore, one of the most important determinants of host resistance is the breed of cattle (Utech *et al.*, 1978). But within a particular breed factors determining the level of resistance include lactation (Rechav, 1992), level of nutrition (Sutherst *et al.*, 1983 and Rechav, 1992) and grooming behaviour (de Castro, 1991 and Minjauw and de Castro, 2000). It is known from Wolayta Zone Rural Development Department Basic Data (2003) that Holstein crosses were kept by animal producers in rural area mainly for milk production, which serve as a means of cash income. Due to this fact such animals possibly exposed to production stress. Hence could be infested by ticks more than the indigenous. It must be expected that if host resistance is reduced by introduction of exotic (*B. taurus*) genes into cattle populations, the tick situation in the area will worsen rapidly. The experience in Australia showed that population of *B. microplus* on cattle increase exponentially as the percentage of *B. indicus* genes in a cattle population is reduced (FAO, 1984). Tick count may generally suggest to farmers as a practical method for culling low productive animals, which are heavily infested with tick regularly.

5. CONCLUSION AND RECOMMENDATIONS

Among the tick species identified in the study areas *B. decoloratus*, *A. variegatum*, *A. gemma* and *A. cohaerens*; and *Rh. evertsi evertsi* were the most abundant, and distributed. They are important external parasites of cattle in Wolayta. The Preferred attachment sites for most of *Amblyomma species* were scrotum/udder, brisket and internal part of legs. Due to this fact they impair productivity and mobility of the animals. *B. decoloratus* will be the major obstacle for introduction and disseminations of exotic cattle and their crosses, being vector of *Babesia*.

Environmental and ecological changes may induce alterations in tick distribution and abundance. From this study result it is possible to conclude that agro-ecology and season play great role in the variation in distribution and abundance of tick species, dynamics. But sex and age of animals are not principally determinant of these variations being we let the animals to graze in the field. When the relative number of certain tick species increased in an area there is also increased rate of infestations. The other factor that influences population of ticks is the host factor (resistance). From this study one of the most important determinants of host resistance is the breed of cattle.

High total tick infestation of Holstein cross was found during both wet and dry periods. But it is significantly higher in wet period than dry period. The total tick burden of indigenous is also higher during wet period as compared to dry period. This variation in total tick burden between the two breeds was observed due to their difference in susceptibility to ticks. Generally the environmental condition of Wolayta is conducive for reproduction of ticks. Therefore, the following recommendations are forwarded to benefit from the livestock production by overcoming the problems encountered due to tick infestations.

- Use of selected tick resistant and comparatively productive indigenous: It is known that the long term use of acaricides to control ticks has been shown to be very problematical. Hence, there is great interest worldwide in the development of alternatives control measures. Among the alternative the use of resistant cattle is one of the approach, which is the cheapest of all the other control methods. Therefore, animal production through selection of highly resistant and productive indigenous should be encouraged. Especially in warm, wet areas a greater proportion of selected indigenous blood is required to have adequate resistance.
- Strategic tick control: Application acaricides aimed at reduction of ticks population based on information about their seasonal activity. That is treating animals two to three times at early rainy season and about two treatments later around the end of rain period to reduce of next tick generations.
- Integrated tick control: These encompasses biological, chemical and ecological control methods, should be used. Alternatively, use of tick resistance breeds of cattle can be combined with short-interval pasture rotation, and with limited level of acaricide use.
- Extension work: Educating animal breeders on the problems of tick, and the different control methods, which can be available in their areas. Successes of ticks control generally associated with good extension work.

- Strengthening animal health service: Ticks are the major obstacle to improve and/or grade- up the indigenous cattle production potential through cross-breeding. Hence, the animal services need to strengthen through infrastructure and man power. The main reasons for failure of some programme are economic constraints, or the technical shortcomings.
- Tick-borne diseases assessment: Importance, distribution, breeds difference and seasonal prevalence of TBD survey should be conducted. Based on the result it is possible to design model of integrated tick and TBD control.

7. REFERENCES

Abdo, J. (1986): Study of geographical distribution of ticks in Gamu-gofa administrative region. DVM thesis, Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit. pp1-37.

Abera, M. (1989): Bovine tick survey in Bahir-Dar Awraja. DVM thesis, Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit. pp.1-21.

Ali, M. and de Castro, J.J. (1993): Host resistance to ticks (Acari: Ixodidae) in different breeds of cattle at Bako, Ethiopia. *Tropical Animal Health and Production*. **25**: 215-222.

Animal Health and Production Compendium (CABI Publishing, 2003).

Aragaw, K. (1994): Study on host resistance to natural infestation in Friesian and indigenous zebu cattle. DVM thesis, Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit. pp.1-34.

Assefa, B. (2004): A survey of ticks and tick-borne blood protista in cattle at Asela, Arssi Zone. DVM thesis, Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit. pp.1-21.

Asrat, G. (1987): Survey of tick on domestic animals in Harrarge administrative region. DVM thesis, Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit. pp.1-30.

Bay, D.E. and Harris, R.L. (1998): Introduction to Veterinary Entomology. A guide to livestock insects. Stonefly publishing, Texas. pp 70-84.

Bekele, T. (1996): Survey on the distribution of ticks of domestic animals in the eastern zone of Ethiopia. *Tropical Animal Health and Production*, **28**: 145-146.

Bekele, T. (2002): Studies on seasonal dynamics of ticks of Ogaden cattle and individual variation in resistance to ticks in eastern Ethiopia. *Journal of Veterinary Medicine*, **49** (6): 285-288.

Belay, S. (2004): A survey of cattle tick species in and around Mizan-Teferi, Bench Maji Zone, and SNNPRS. DVM thesis, Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit. pp.1-21.

Bergeon, P. and Balis, J. (1974): Contribution á l`étude dela répartition des tiques en Ethiopie. *Rev. Elev.Méd. Vét pays trop.*, **27** (3): 285 -299.

Berhane, M. (2004): Distribution of livestock tick species in Awassa area. DVM thesis, Addis Ababa University, Faculty veterinary Medicine, Debre-Zeit. pp.1-16.

Biru, S. (1988): A preliminary survey of ticks' distribution in the southern Sidamo. DVM thesis, Addis Ababa University, Faculty veterinary Medicine, Debre-Zeit. pp.1-29.

Brossard, M. (1998): The use of vaccine and genetically resistant animals in tick control: In genetic resistance to animal diseases. Rev. Sci. tech. Off. Int. Epiz. 17 (1): 188-199.

Brown, S.J. (1985): Immunology of acquired resistance to ticks. *Veterinary Parasitology*, **1** (60): 166-171.

CSA (2003): Ethiopian Agricultural sample enumeration results for SNNPR. Statistical report on livestock and farm implements, part IV. pp.29- 304.

de Castro, J.J (1991): Resistance to Ixodid ticks in cattle with an assessment of its role in tick control in Africa. In: Owen, J.B. and Axford, R.F.E. edition Breeding for diseases resistance in farm animals, first edition. CAB International, Wallingford. pp.244-262.

de Castro, J.J. (1994): A survey of the tick species in western Ethiopia including the previous findings and recommendation, for further tick survey in Ethiopia. Technical report AG: DP/ETH/83/023. FAO, Rome. pp.1-83.

de Castro, J.J. (1997a): Long term studies on the economic impact of ticks on sanga cattle in Zambia. *Experimental Applied Acarology,* **21**: 3-19.

de Castro, J.J. (1997b): Sustainable tick and tick-borne diseases control in livestock improvement in developing countries. *Veterinary Parasitology*, **71**: 77-97

Dioli, M.; Jean-Baptiste, S. and Fox, M. (2001) : Ticks (Acari : Ixodidae) of the one-humped camel (*Camelus dromedarious*) in Kenya and Southern Ethiopia: Species composition, attachment sites, sex ratio and seasonal incidence. *Revue Elev. Med. Vet. Pays trop*., **54** (2): 115-122.

Dossa, S.C.; Kaaya, G.P.; Essumans, S.; Odulaja, A. and Assoku, R.G.K. (1996): Acquisition of resistance to the tick *Amblyomma variegatum* in Boran cattle, *Bos indicus*, and the effect of *Trypanosoma congolense* and *Babesia bigemina* on host resistance. *Veterinary Parasitology,* **62**: 317-330.

Dreyer, K.; Fourie, L. and Kok, D.J. (1997): Tick control in urban environments. Proceedings of an International seminar on primary animal health activities in South Africa held at Mzuzu, Malawi, February 26 to March 8, 1996. DSE, Federal Republic of Germany. pp. 294-300.

Dhuffera, W. (1997): Survey of ticks and tick-borne diseases in eight domestic animals in and around Debre-Zeit, Eastern shewa. DVM thesis, Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit. Pp. 1-79

Elder, J.K.; Waters, K.S.; Dunwell, G.H.; Emmerson, F.R.; Kearnan, J.F.; Morris, R.S. and Knot, S.G. (1980): A survey concerning cattle tick control in Queens Land-2. Managerial Aspects which directly affect tick control. *Australian Veterinary Journal*, **56** (5): 212-218.

FAO (1984): Ticks and tick-borne disease control. A practical field manual, Vol. 1. Tick control. FAO, Rome, pp.1-299.

FAO.AGAL (2003): Livestock sector brief, Ethiopia.

Gardie, D. (1988): A preliminary survey of ticks on domestic animals in Bale administrative region. . DVM thesis, Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit. Pp. 1-28.

Gashaw, A. (2004): Seasonal dynamics and host preference of Boophilus decoloratus (Koch, 1944) on naturally infested cattle in Jimma zone, South western Ethiopia. *Ethiopian Veterinary Journal*, **18** (1): 19-28.

Gebreab, F. (1983): Notes on ticks species and tick-borne diseases of domestic animals in Ethiopia. Faculty of Veterinary Medicine, Adds Ababa University. pp.1-64.

G/Michael, T. (1993): Ticks and tick-borne diseases of cattle in North Omo Zone**.** DVM thesis, Addis Ababa University, Faculty veterinary Medicine, Debre-Zeit. pp.1-50.

Getachew, Y. (2004): Tick species infesting livestock in Jimma area, Southwest Ethiopia. DVM thesis, Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit. pp.1-19.

Haile, B. (1987): Study of the topographical distribution of ticks on economically important domestic animals in Illubabor. DVM thesis, Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit. pp. 1-46.

Hatsur, T. (1991): Identification of tick of species and distribution in cattle, camel, sheep, and goats of eastern Harrarge. DVM thesis, Addis Ababa University, Faculty veterinary Medicine, Debre-Zeit. pp.1-29.

Hendrix, C.M. (1998): Diagnostic Veterinary Parasitology, 2nd edition. Mosby, Inc. pp. 164-227.

Hoogstraal, H. (1956): African Ixodidae. (I) Ticks of Sudan (with special to Fquatoria province and with preliminary reviews of the genera Boophilus, Margaropus, Hyalomma). Res. Rep. N.M., 005050. 29-07. U.S Government Department of Navy, Bur. Med. Surg., Washington, D.C. pp. 200-1101.

Hopla, C.E.; Durden, L.A. and Keirans, J.E. (1994): Ectoparasites and classification. Rev. Sci. tech. Off. Int. Epiz., 13 (4): 985-1017.

Howell, C.J.; Walker, J.B. and Nevill, E.M. (1978): Ticks, mites and insects infesting domestic animals in South Africa. Republic of South Africa Department of Agricultural Technical Services Science Bulletin 393. Perskor, Pretoria. pp. 1-35.

ILRI (1999): Making the livestock revolution work for poor, annual report. ILRI, Nairobi, Kenya. pp.1-32.

Jayasuriya, M.C.N. (1999): Summary of the coordinated project on development of feed supplementation strategies for improving the productivity of dairy cattle on smallholder farms in Africa. Animal production and health section, IAEA. pp. 1-5.

Jongejan, F. and Uilenberg, G. (1994): Ticks and control methods. Ectoparasites of animals and control methods. Rev. Sci. tech. Off. Int. Epiz., 13 (4), pp. 1201-1226.

Jubb, K.V.; Kennedy, P.C.; and Palmer, N. (1993): Pathology of Domestic Animals. Volume 1, 4th edition. Academic Press, Inc. pp. 691.

Kaiser, M.N.; Sutherst, R.W. and Bourne, A.S. (1982): Relationship between ticks and zebu cattle in Southern Uganda. *Tropical Animal Health and Production*, **14**: 63-74.

Kaiser, M.N.; Sutherst, R.W., Bourne, A.S.; Gorissen, L. and Floyed, R.B. (1988): Population dynamics of ticks on Ankole cattle in five ecological zones in Burundi and strategies for their control. *Preventive Veterinary Medicine*, **6**: 199- 222.

Kaiser, M.N.; Sutherst, R.W., and Bourne, A.S. (1991): Tick (Acarina: Ixodidae) infestation on Zebu cattle in northern Uganda. *Bulletin of Entomological Research,* **81**: 257- 262.

Katherine, M.K. (1976): Ticks of Veterinary importance. Animal and plant health inspection service, United States Department of Agriculture, Agriculture Handbook number 485. pp. 1-122

Kaufmann, W.R. (1989): Tick-host interaction: A synthesis of current concepts. *Parasitology Today*, **5** (2): 47-55.

Kettle, D.S. (1995): Medical and Veterinary Entomology. Second edition, CAB International, Wallingford, Oxon, UK. pp. 440-485.

Latif, A and Jongejan, F (2002): The wide-use of acaricide for the control of tick on Livestock in Africa needs a reappraisal. ICPTV, No 6, pp. 10-12.

Latif, A.A. and Walker, A R. (2004): An introduction to the biology and control of ticks in Africa. ICTTD-2 project. Pp. 1-29.

Lorenz, K.; Leidl, K.; Hörchner, F. and Schein, E. (1996): Strategic tick control on local zebu cattle in Malawi with special reference to the calves: Effects on disease incidence and economic aspects in two different ecological zones. Pro. Int. Sem. On Anim. Health Activ. In Southern Africa. Mzuzu, Malawi. Pp. 131-135.

Mamo, E. (1988): Study of geographical distribution of ticks in Gondar Awraja. DVM thesis, Addis Ababa University, Faculty Veterinary Medicine, Debre Zeit. pp.1-33.

Matthee, S.; Meltzer, D.G.A. and Horak, I.G. (1997): Sites of attachment and density assessment of ixodid ticks (Acari: Ixodidae) on impala (Aepyceros melampus). *Experimental and Applied Acarology*, **21**: 179-192.

Mattioli, R.C.; Janneh, L.; Corr, N.; Faye, J.A.; Pandey, V.S. and Verhulst, A. (1997): Seasonal prevalence of ticks and tick transmitted haemoparasites in traditionally managed N'Dama cattle with reference to strategic tick control in the Gambia. *Medical and Veterinary Entomology*, **11** (11):342-348.

Mekonnen, S. (1994): Tick and tick-borne Diseases Control in Ethiopia. Tick and Tick-borne diseases control in Eastern, Central and Southern Africa, 1991-1994. Proceeding of a joint OAU, FAO and ILRAD workshop held in Lilongwe, Malawi 25-28 April 1994. pp. 19- 21.

Mekonnen, S. (1998): Ticks, tick-borne diseases and control strategies in Ethiopia, Proceedings of the second International conference on tick-borne pathogens at the host-vector interface: a global perspective. August 20- September 1, 1995, Kruger National Park, South Africa. pp. 441-446.

Mekonnen, S.; Hussein, I. and Bedane, B. (2001): The distribution of Ixodid ticks in central Ethiopia. *Onderstepoort Journal of Veterinary Research*, **68** (4): 243-251.

Mekuria, B. (1987): A preliminary survey of ticks on four species of domestic animals in Nekemte Awraja. . DVM thesis, Addis Ababa University, Faculty of Veterinary Medicine, Debre-Zeit. pp.1-35.

Mesfin, S. (1996): Survey on ticks in four domestic animals in Tigray Region. DVM thesis, Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit. pp. 1-40.

Minjauw, B. and de Castro, J.J (2000): Host resistance to ticks and tick-borne diseases: Its role in integrated control. *Breeding for Diseases Resistance in Farm Animals*. CAB International, pp. 153-169.

Minjauw, B. and McLeod, A. (2003): Tick-borne diseases and poverty. The impact of ticks and tick-borne diseases on the livelihood of small-scale and marginal livestock owners in India and eastern and southern Africa. Research report, DFID Animal Health Programme, center for Tropical Veterinary Medicine, University of Edinburgh, UK. Pp. 1-116.

Moran, M.C.; Nigarura, G. and Pegram, R.G. (1996): An assessment of host resistance to ticks on cross-bred cattle in Burundi. *Medical and Veterinary Entomology*, **10**: 12-18.

Morel, P. (1980): Study on Ethiopian ticks (Acarida, Ixodida). Republic of France, Ministry of Foreign Affairs, French Vet. Mission, Addis, C.J.E.M.V.T., pp.7-332.

Morel, P. (1989): Manual of Tropical Veterinary Parasitology, Tick- borne Diseases of Livestock in Africa. CAB International, UK. pp. 299-460.

Naser, M. (1985): Common tick species in Wolayta Awraja. DVM thesis, Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit. pp.1-38.

National Meteorological Service Agency (2004/5): Basic meteorological data of Wolayta Soddo.

Okello-Onen, J.; Hassan, S.M. and Essuman, S. (1999[a]): Taxonomy of African ticks, an identification manual. International Center for Insect Physiology and Ecology press, Nairobi, Kenya, pp.1-124.

Okello-Onen, J.; Tukahirwa, E.M.; Pery, B.D.; Rowlands, G.J.; Nagda, S.M.; Musisi, G.; Bode, E.; Heinonen, R.; Mway, W.; and Opuda-Asibo, J. (1999[b]): Population dynamics of ticks on indigenous cattle in a pastoral dry to semi-arid rangeland zone of Uganda. *Exp. Appl. Acarol.*, **23**: 79-88.

Pegram, R.G.; Hoogstraal, H.; and Wassef, H.P. (1981): Ticks (Acari: Ixodoidea) of Ethiopia. I. Distribution, Ecology and Host relationship of species infecting livestock. *Bulletin of Entomology Research*, **71**: 339-359.

Petney, T.N.; Horak, I.G. and Rechave, Y. (1992): The Ecology of the African vectors of heartwater, with particular reference to *Amblyomma hebraeum* and *Amblyomma variegatum*. *Onderstepoort J. Vet. Res*. **54**: 381-395.

Randolph, S.E. (1994): Population dynamics and density- dependent seasonal mortality indices of the tick *Rhipicephalus appendiculatus* in eastern and southern Africa. *Medical and Veterinary Entomology*, **8**: 351- 368.

Randolph, S.E. (1997): Abiotic and biotic determinants of seasonal dynamics of the tick *Rhipicephalus appendiculatus* in eastern and southern Africa. *Medical and Veterinary Entomology*, **11**: 25- 37.

Randolph, S.E.; Green, R.M.; Hoodless, A.N. and Peacey, M.F. (2002): An empirical framework for the seasonal population dynamics of the ticks *Ixodes ricinus*. *International Journal for Parasitology*, **32**: 979- 989.

Rechav, Y. (1992): Naturally acquired resistance to ticks – A global view. *Insect Science and its application*, **13**: 495-504.

Regassa, A (2001): Tick infestation of Boran cattle in the Boran Province of Ethiopia. *Onderstepoort Journal of Veterinary Research*, **68**: 41- 45.

Seyoum, Z. (2001): Study of ticks and tick-borne diseases on zebu cattle at Girana Valley in north Wollo Zone. EVA proceedings of the 15th conference, pp. 128- 143.

Sinshaw, S. (2000): Distribution of ticks and tick-borne diseases at Metekel Ranch. *Ethiopian Veterinary Journal* **1** (4): 40-59.

Solomon, G. (1993): Resistance of three breeds of cattle to ticks and tick-borne diseases at Abernossa ranch, Ethiopia. Proceeding of the seventh Ethiopian Veterinary Association Conference. Pp. 78-99.

Solomon, G. and Kaaya, G.P. (1996): Comparison of resistance in three breeds of cattle against African Ixodid ticks. *Experimental and applied acarology*, **2** (4): 223-230.

Solomon, G. and Kaaya, G.P. (1998): Development, reproductive capacity and survival of *Amblyomma variegatum* and *Boophilus decoloratus* in relation to host resistance and climatic factors under field condition, *Veterinary Parasitology*, **75** (2/3): 241- 253.

Solomon, G; Kaaya, G.P; Gebreab, F; Gemechu, W; and Tilahun, G (1998): Tick and tick-borne parasites associated with indigenous cattle in Didytuyura ranch. *Insect science and its application*, **18** (1): 59-66.

Solomon, G., Nigist, M., and Kassa, B. (2000): Seasonal variation of ticks on calves at Sebeta in western Shewa zone. *Ethiopian Veterinary Journal,* **7** (1&2): 17-30.

SPSS 11.5 for Windows: SPSS Inc., 1989 – 2002 LEAD Technologies

Susan, E. Aiello (1998): The Merck Veterinary Manual. 8th edition, Merck and Co. Inc., USA. pp. 670-686.

Sutherst, R.W.; Kerr, J.D.; Maywald, G.D. and Stegeman, D.A. (1983): The effect of season and nutrition on the resistance of cattle to the host, *B. microplus*. *Australian Journal of Agricultural Research*. **34**: 329

Sutherst, R.W.; Floyed, R.B.; Bourne, A.S. and Dallwitz, M.J. (1986): Cattle grazing behaviour regulates tick population. *Experientia*, **42**: 194 – 196.

Sutherst, R.W. and Utech, K.B.W. (1981): Controlling livestock parasite with host resistance, In: CRC Handbook of Pest management in Agriculture, Vol. II. CRC press, Boca Raton, pp. 385- 407.

Sutherst, R. W. (1987[a]): Tick ecology: The importance of population dynamics in developing national tick control and eradication programmes. In: the eradication of ticks, Proceedings of the expert consultation on the eradication of ticks with special reference to Latin America, Mexico, 22 – 26 June 1987. pp. 196 - 210.

Sutherst, R. W. (1987[b]): Resistance of cattle to ticks as one element in a tick control programme: The importance of population dynamics in developing national tick control and eradication programmes. In: the eradication of ticks, Proceedings of the expert consultation on the eradication of with special reference to Latin America, Mexico, 22 – 26 June 1987. pp. 154 - 164 .

Tadesse, M. (1994): Survey on mange mites and ticks of camel and small ruminants in Dire-Dawa Region. DVM thesis, Addis Ababa University Faculty of Veterinary Medicine, Debre-Zeit. PP. 1-25.

Tamire, M. (2003): Comprehensive Geography. Mega Publishing Enterprise, Addis Ababa. pp. 249-294.

Tatchell, R.J. (1987): Interaction between ticks and their hosts. *International Journal for Parasitology,* **17**: 597-605.

Thrusfield, M. (1995): Veterinary Epidemiology, Second edition. U.K. Black well science Ltd. pp. 182-198.

Torr, S.; Eisler, M.; Coleman, P.; Morton, J. and Machila, N. (2003): Integrated control of ticks and tsetse. A report for the DFID advisory and support service contract, project ZV 0151; NRI code V 0160. pp. 1-135.

Utech, K.B.W.; Wharton, R.H. and Kerr, J.D. (1978): Resistance to *Boophilus microplus* (Canestrini) in different breeds of cattle. *Aust. J. Agric. Res*., **29**: 885-895.

Walker, A.R.; Bouattour, A.; Camicas, J.L.; Estrada-Pena, A; Horak, I.G.; Latif, A.A.; Pegram, R.G. and Preston, P.M. (2003): Ticks of domestic animals in Africa: a guide to identification of species. Bioscience report. pp. 1-221.

Wall, R. and Shearer, D. (1997): Veterinary entomology. Champan and Hall publisher. pp. 96-139.

Wellcome (1976): Cattle tick control. Wellcome Research Organization, Second edition. Cooper Division Wellcome Foundation Ltd. London, England. pp. 1-65.

Wikel, S.K. and Allen, J.E. (1976): Acquired resistance to ticks. I. Passive transfer of resistance. *Immunology*, **30**: 311-316.

Wikel, S.K. and Allen, J.E. (1977): Acquired resistance to ticks. III. Cobra Venom factor and the resistance response. *Immunology*, **32**:457-465.

Wikel, S.K. and Whelen, C. (1986): Ixodid-host immune interaction. Identification and characterization of the relevant antigens and tick-induced host immunosuppression. *Veterinary Parasitology*, **20**: 149-174.

Wolayta Zone Rural Development Department (2003): Basic data of Wolayta Zone Agricultural Development.

Wolayta Zone Finance and Economic Development Department (2003): Socio-economic profiles of Wolayta Zone. pp. 1- 97.

Yohualashet, T.; Gebreab, F.; Wakijira, A and Tsega, T (1995): Preliminary observation on ticks: seasonal dynamics and resistance of three indigenous and three crossbreed cattle in Ethiopia. *Bulletin of Animal Health and Production in Africa*, **43** (2): 114.

Yilma, J.M.; Daniel, W.S. and Dorchies, P. (1995): Survey of ticks infesting domestic ruminants in South Wollo Region of Ethiopia. *Revue de Medicine Veterinaire*, **146** (3): 213- 220.

6. ANNEXES

Annex 1. Agro-ecological pairwise comparison of the mean distribution of the tick species identified from the study areas

Tick species	(I) Agro-ecological	(J) Agro-ecological	Mean Difference │I-J│	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
	Highland	Midland	1.145(*)	0.331	0.001	0.496	1.794
A. variegatum		Lowland	1.605(*)	0.331	0.000	0.956	2.254
	Midland	Lowland	0.460	0.331	0.164	0.189	1.109
	Highland	Midland	1.438(*)	0.294	.000	0.862	2.015
A. gemma		Lowland	2.112(*)	0.294	0.000	1.536	2.689
	Midland	Lowland	0.674(*)	0.294	0.022	0.097	1.250
	Highland	Midland	0.014	0.131	0.912	-0.272	0.243
		Lowland	0.627(*)	0.131	0.000	0.370	0.884
A. cohaerens	Midland	Lowland	0.612(*)	0.131	0.000	0.355	0.869
	Highland	Midland	0.228(*)	0.106	0.031	0.021	0.435
A. lepidum		Lowland	-0.072	0.106	0.493	-0.280	0.135
	Midland	Lowland	0.301(*)	0.106	0.004	0.094	0.508
	Highland	Midland	0.159	0.312	0.610	-0.454	0.772
B. decoloratus		Lowland	2.029(*)	0.312	0.000	1.416	2.642
	Midland	Lowland	1.870(*)	0.312	0.000	1.256	2.483
	Highland	Midland	0.225(*)	0.089	0.012	0.050	0.399
Rh. e. evertsi		Lowland	0.460(*)	0.089	0.000	0.286	0.634
	Midland	Lowland	0.236(*)	0.089	0.008	0.061	0.410
	Highland	Midland	0.004	0.041	0.929	-0.077	0.084
Rh. muhsamae		Lowland	0.029	0.041	0.478	-0.051	0.109
	Midland	Lowland	0.033	0.041	0.425	-0.048	0.113
	Highland	Midland	0.040	0.044	0.361	-0.046	0.125
Rh. guilhoni		Lowland	0.058	0.044	0.184	-0.028	0.143
	Midland	Lowland	0.018	0.044	0.678	-0.067	0.104

* The mean difference is significant at the 0.05 level.

(a) Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Annex 2. Mean number of tick species identified from each agro-ecological zones and the 95% confidence interval

Dependent Variable	Agro-ecol	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
	Highland	1.790	0.234	1.331	2.249
A. variegatum	Midland	2.935	0.234	2.476	3.394
	Lowland	3.395	0.234	2.936	3.854
	Highland	1.938	0.208	1.531	2.346
A. gemma	Midland	3.377	0.208	2.969	3.784
	Lowland	4.051	0.208	3.643	4.458
	Highland	0.812	0.093	0.630	0.993
A. cohaerens	Midland	0.797	0.093	0.615	0.979
	Lowland	0.185	0.093	0.003	0.367
	Highland	0.373	0.075	0.227	0.520
A. lepidum	Midland	0.601	0.075	0.455	0.748
	Lowland	0.301	0.075	0.154	0.447
	Highland	7.775	0.221	7.342	8.209
B. decoloratus	Midland	7.616	0.221	7.182	8.049
	Lowland	5.746	0.221	5.313	6.180
	Highland	0.236	0.063	0.112	0.359
Rh. e. evertsi	Midland	0.460	0.063	0.337	0.583
	Lowland	0.696	0.063	0.572	0.819
	Highland	0.123	0.029	0.066	0.180
Rh. muhsamae	Midland	0.127	0.029	0.070	0.184
	Lowland	0.094	0.029	0.037	0.151
	Highland	0.080	0.031	0.019	0.140
Rh. guilhoni	Midland	0.120	0.031	0.059	0.180
	Lowland	0.138	0.031	0.077	0.198

Annex 3. Effects of the interaction of agro-ecology and season on tick species distribution

Tick species	Source	Type III Sum of Squares	df	Mean Square	F	Signif.
	Corrected Model	2122.750(a)	5	424.550	19.040	0.000
	Intercept	6427.837	1	6427.837	288.278	0.000
A. variegatum	Agro-ecology	534.804	2	267.402	11.993	0.000
	Season * Agroecol	228.379	2	114.190	5.121	0.006
	Corrected Model	1312.435(a)	5	262.487	20.399	0.000
A. gemma	Intercept	7344.391	1	7344.391	570.766	0.000
	Agro-ecology	574.717	2	287.359	22.332	0.000
	Season * Agroecol	604.597	2	302.298	23.493	0.000
	Corrected Model	220.942(a)	5	44.188	17.360	0.000
	Intercept	306.783	1	306.783	120.527	0.000
A. cohaerens	Agro-ecology	67.109	2	33.554	13.183	0.000
	Season * Agroecol	107.437	2	53.719	21.105	0.000
	Corrected Model	192.560(a)	5	38.512	2.338	0.040
	Intercept	255.556	1	255.556	15.515	0.000
	Agro-ecology	81.104	2	40.552	2.462	0.086
A. lepidum	Season * Agroecol	84.283	2	42.141	2.558	0.078
	Corrected Model	1411.000(a)	5	282.200	9.793	0.000
	Intercept	42269.391	1	42269.391	1466.819	0.000
	Agro-ecology	330.986	2	165.493	5.743	0.003
B. decoloratus	Season * Agroecol	606.734	2	303.367	10.527	0.000
	Corrected Model	81.238(a)	5	16.248	13.097	0.000
	Intercept	206.001	1	206.001	166.052	0.000
	Agro-ecology	44.705	2	22.353	18.018	0.000
Rh. e. evertsi	Season * Agroecol	5.227	2	2.614	2.107	0.122

(a) R Squared = 0.104 (Adjusted R Squared = 0.098)

$\alpha = 0.05$

Annex 4. Table to show analysis of seasonal variation of the major tick species taking in to consideration all the study areas together (Two-sample t- test with equal variances)

Tick species	Season	Mean	Std. Error	Std. Dev.	t - Value	P > |t|	[95% Conf. Interval]
	Wet	4.111	0.252	5.121			3.616 - 4.606
A. variegatum	Dry	1.302	0.107	2.176	10.2719	0.0000 * * *	1.092 - 1.512
	Wet	2.150	0.141	2.875			1.872 - 2.428
A. gemma	Dry	4.094	0.207	4.212	-7.7583	0.0000 * * *	3.687 - 4.501
	Wet	0.841	0.094	1.913			0.656 - 1.025
A. cohaerens	Dry	0.355	0.060	1.212	4.3619	0.0000 * * *	0.238 - 0.472
	Wet	0.372	0.053	1.070			0.269 - 0.475
A. lepidum	Dry	0.478	0.069	1.410	-1.2217	0.2222^{NS}	0.342 - 0.615
	Wet	6.324	0.174	3.546			5.981 - 6.666
B. decoloratus	Dry	7.768	0.203	4.137	-5.3937	0.0000 * * *	7.368 - 8.168
	Wet	0.623	0.061	1.236			0.504 - 0.743
Rh. e. evertsi	Dry	0.304	0.042	0.849	4.3258	0.0000 * *	0.222 - 0.386

Degrees of freedom: 826 Obs Wet= 414 and Dry= 414

Annex 5. Repeated measure analyses results of half-body region total tick burden count

Mean monthly half-body regions total tick burden repeated measure adjusted univariate test result of within-subjects (in each breed between months).

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Month	Sphericity Assumed	23.574	7	3.368	185.843	0.000
	Greenhouse-Geisser	23.574	4.633	5.088	185.843	0.000
Month * Ago-ecology	Sphericity Assumed	1.944	14	0.139	7.663	0.000
	Greenhouse-Geisser	1.944	9.266	0.210	7.663	0.000
Error (Month)	Greenhouse-Geisser	5.708	208.480	0.027		

Within subject design: Month

Comparison of Holstein cross and indigenous cattle half-body regions monthly burden variation at Kokatie

Breed	Mean difference	Std. Error	Sig.[a]	95% Confidence Interval for Difference(a)	
Holstein cross and Indigenous	0.443(*)	0.023	0.000	0.396	0.489

Based on estimated marginal means

* The mean difference is significant at the 0.05 level.

[a] Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Annex 6. Field survey data of total tick burden count of the study areas

Ago.Ecol.	Sex	Age	Breed	August	September	October	November	December	January	February	March
1	2	1	3	249	131	152	98	38	45	15	30
1	1	1	3	67	60	53	85	50	50	22	54
1	1	1	3	42	24	68	65	28	22	23	33
1	1	1	3	45	38	62	37	43	39	8	24
1	1	1	3	128	128	98	47	27	34	34	44
1	2	1	3	167	161	103	88	42	28	37	36
1	1	1	3	173	134	133	137	65	70	33	51
1	2	1	3	149	72	136	47	47	25	16	17
1	2	2	3	58	32	55	46	32	17	9	22
1	1	2	3	150	69	73	88	47	46	17	30
1	1	2	3	180	117	121	63	38	24	40	44
1	1	2	3	300	166	117	76	46	36	17	22
1	2	2	3	233	122	108	94	41	41	43	27
1	1	2	3	61	95	116	93	39	37	30	41
1	1	2	3	107	121	68	89	42	26	20	49
1	2	2	3	70	58	83	52	38	22	29	31
2	1	1	3	125	159	143	40	43	42	22	71
2	1	1	3	74	109	80	70	56	30	25	52
2	2	1	3	94	111	75	56	37	41	46	86
2	2	1	3	152	175	129	52	47	33	37	54
2	2	1	3	75	133	93	58	53	31	31	38

Ago.Ecol.	Sex	Age	Breed	August	September	October	November	December	January	February	March
2	2	1	3	124	159	140	81	58	44	30	48
2	1	1	3	123	151	127	61	51	33	27	67
2	1	1	3	125	129	106	74	63	39	24	36
2	2	2	3	159	166	112	100	42	33	20	50
2	2	2	3	85	133	154	130	27	28	28	61
2	1	2	3	186	135	153	73	44	19	17	49
2	1	2	3	118	134	62	47	20	20	59	50
2	1	2	3	85	182	150	71	37	22	51	105
2	1	2	3	94	114	92	98	66	28	23	56
2	1	2	3	106	127	120	61	21	18	41	106
2	1	2	3	101	112	74	51	22	20	12	51
2	1	1	4	334	337	264	146	103	49	82	135
2	2	1	4	426	405	390	292	234	124	70	106
2	1	1	4	274	313	242	145	216	96	70	128
2	1	1	4	320	270	259	174	236	120	110	165
2	2	1	4	371	321	391	180	136	97	56	111
2	2	1	4	223	225	206	237	220	111	53	118
2	2	1	4	177	218	193	151	126	62	87	100
2	1	1	4	183	231	188	191	223	121	123	151
2	1	2	4	329	309	232	171	166	56	41	166
2	1	2	4	243	235	238	269	231	127	54	204
2	2	2	4	444	286	272	255	195	101	90	119
2	2	2	4	296	311	296	169	221	46	94	140
2	2	2	4	217	316	296	142	116	33	72	133
2	1	2	4	232	292	323	244	138	67	116	251

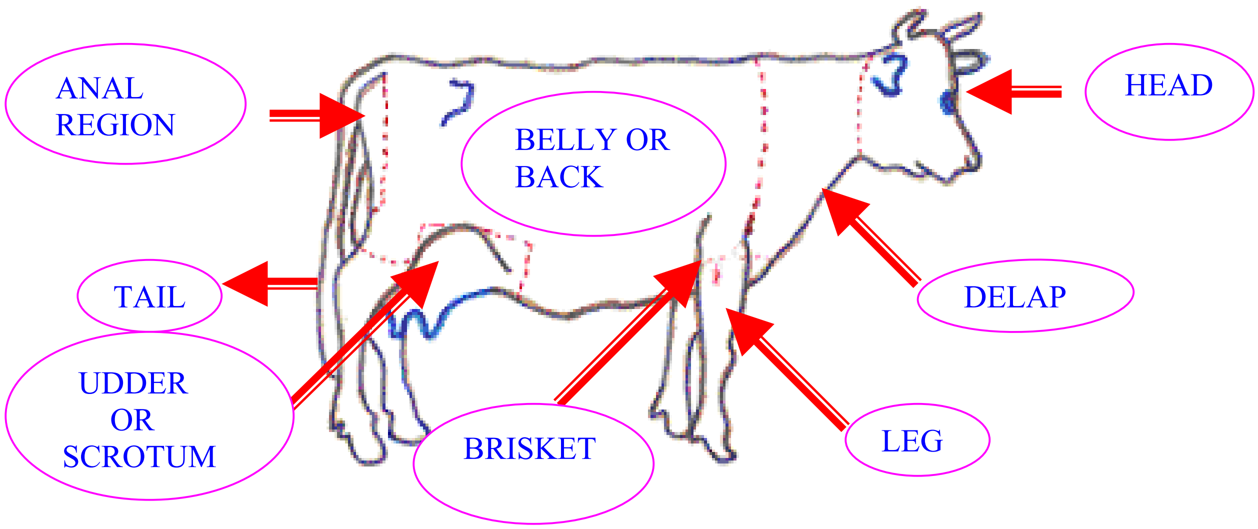
Ago.Ecol.	Sex	Age	Breed	August	September	October	November	December	January	February	March
2	1	2	4	349	350	441	305	243	74	102	250
2	1	2	4	341	387	366	358	232	56	117	233
3	2	1	3	143	138	129	78	57	30	26	18
3	1	1	3	87	122	120	36	32	18	20	11
3	1	1	3	203	129	102	70	96	22	21	20
3	2	1	3	69	76	132	97	54	30	27	31
3	1	1	3	126	117	182	101	102	24	31	43
3	1	1	3	93	102	98	63	48	17	22	18
3	2	1	3	87	110	167	170	66	22	12	28
3	1	1	3	66	66	52	98	64	13	28	19
3	2	2	3	157	109	138	108	72	12	18	23
3	2	2	3	63	77	69	34	32	13	18	27
3	1	2	3	54	96	92	90	73	33	31	33
3	1	2	3	78	67	104	68	51	18	21	23
3	1	2	3	77	95	110	63	50	23	35	32
3	2	2	3	69	112	83	43	26	22	25	20
3	2	2	3	119	121	116	97	67	14	31	34
3	1	2	3	77	100	138	118	38	17	17	16

NB * Agro-ecology: 1 = Highland, 2 = Midland, 3 = Lowland
* Sex: 1 = female, 2 = Male
* Age: 1 = 1 – 4 years, 2 = Above 4 years
* Breed: 3 = Indigenous, 4 = Holstein cross

Annex 7. Tick species identified from half-body of cattle per agro-ecological zone in the wet and dry periods.

Name of ticks	Highland		Midland		Lowland		Total	
	Wet period (138 cattle)	Dry period (138 cattle)	Wet period (138 cattle)	Dry period (138 cattle)	Wet period (138 cattle)	Dry period (138 cattle)	Male	Female
1) Amblyomma								
A. gemma	246	289	312	620	332	786	1694	891
A. variegatum	426	68	594	216	682	255	1398	846
A. cohaerens	210	14	92	128	46	5	326	169
A. lepidum	68	35	52	114	34	49	259	90
2) Boophilus								
B. decoloratus	960	1186	1088	1014	570	1016	2324	3510
3)Rhipicephalus								
Rh. e. evertsi	44	21	100	27	114	78	260	124
Rh. muhsamae	30	4	27	8	6	20	64	31
Rh. guilhoni	22	-	24	9	22	16	68	25
Rh. praetextatus	8	-	-	-	10	13	21	10
Rh. pravus	-	-	-	-	4	-	4	-
4). *Hyalomma*								
Hy. m. rufipes	32	-	-	-	36	-	42	26

Annex 8. Figure to show cattle body regions used for tick burden counting and tick sampling (Modified from Kaiser, 1982).



Annex 9. Pictures to show tick infestations in the study areas.

Plate 1. Teat infestation by mixed *Amblyomma species* (Midland)

Plate 2. Holstein cross Neck and Dewlap infestation by Boophilus decoloratus (Midland)

Plate 3. Udder infestation by *Amblyomma gemma* (Top Male and Lower Female)

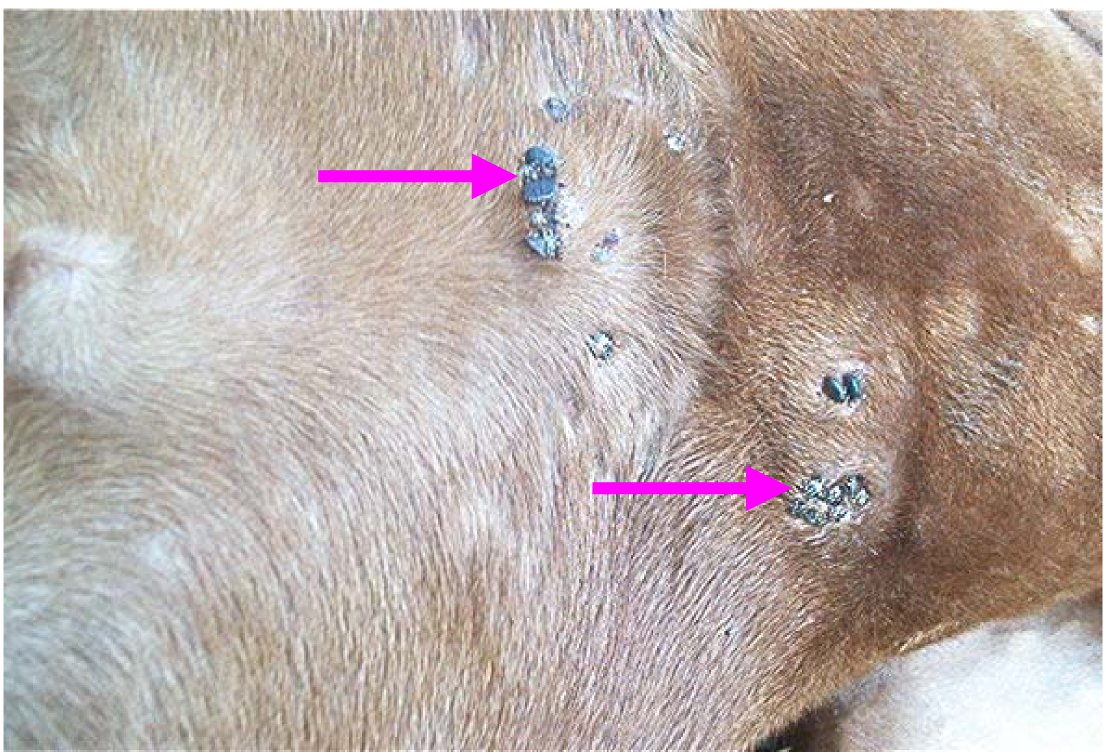


Plate 4. Brisket infestation by mixed *Amblyomma species* (*A.gemma and A.variegatum*)

Annex 10. Map of Ethiopia to show tick distribution in Ethiopia

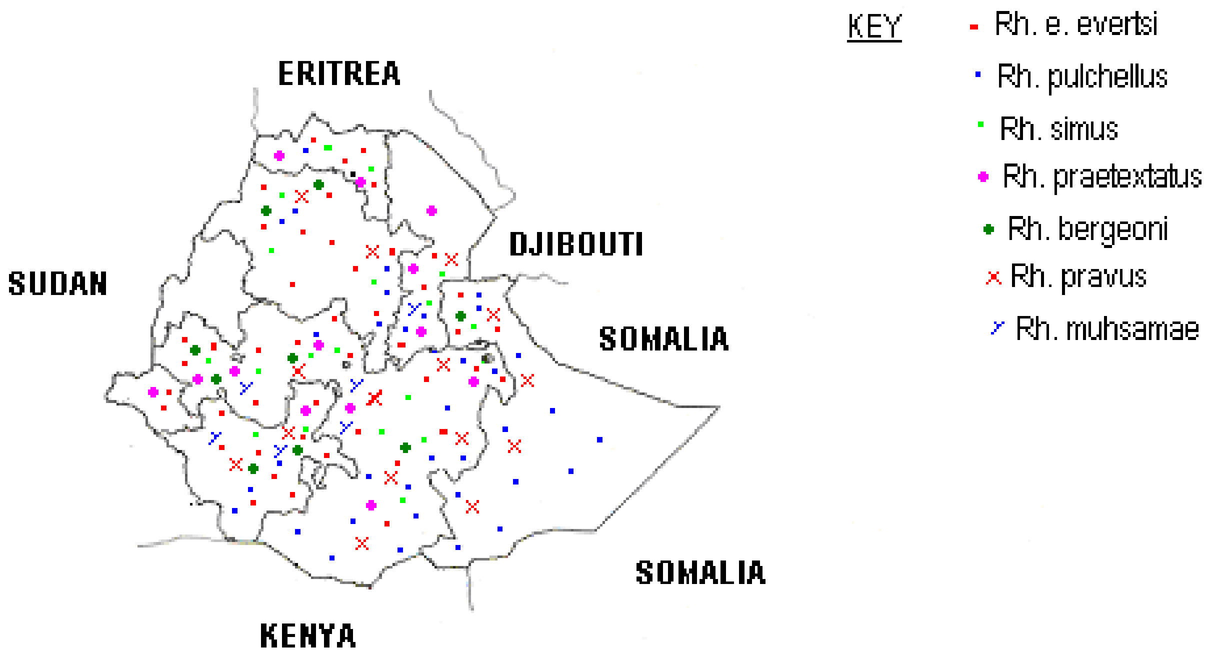


Plate 1. Distribution of the common *Rhipicephalus* species in Ethiopia

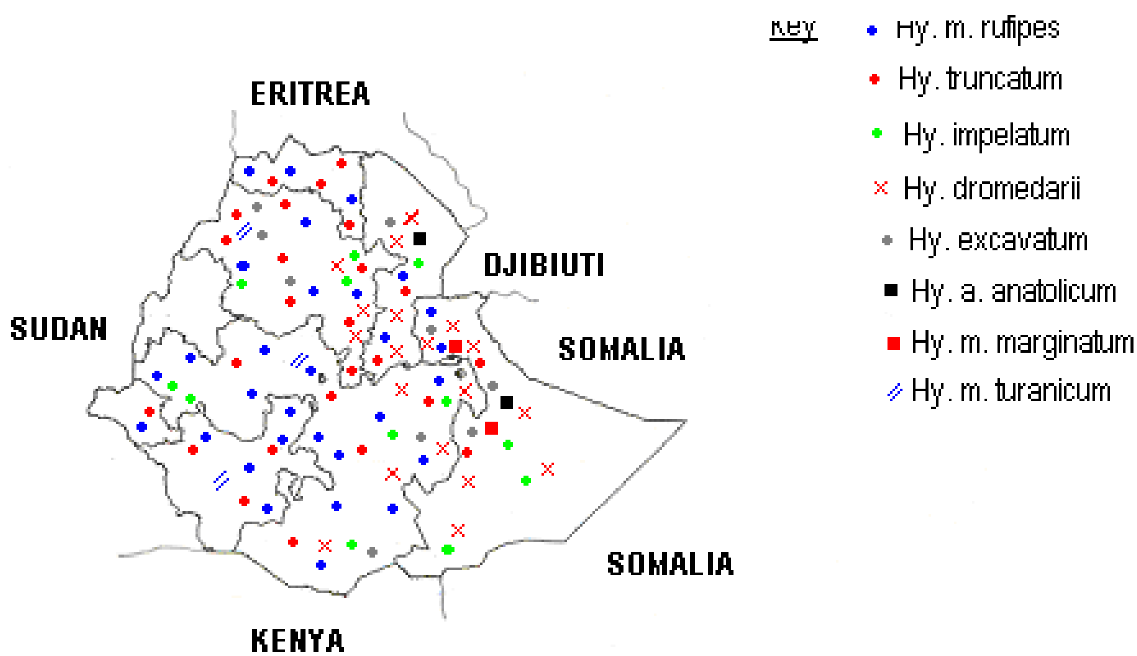


Plate 2. Distribution of the common *Hyalomma* species in Ethiopia

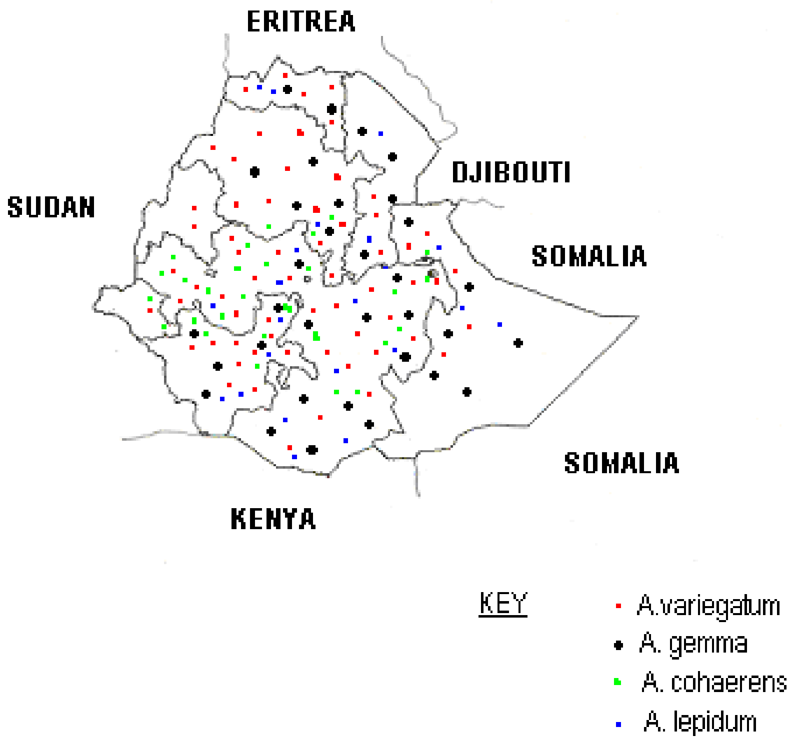


Plate 3. Distribution of *Amblyomma* species

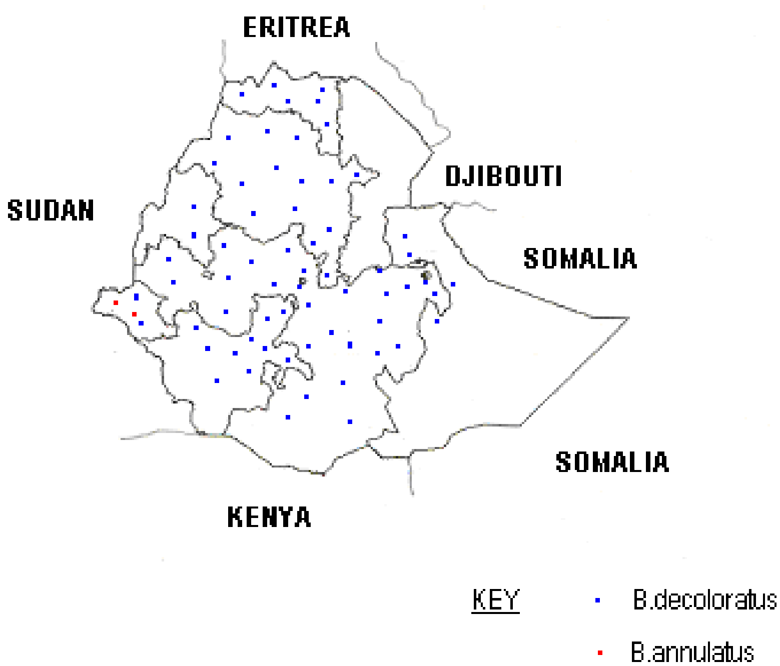
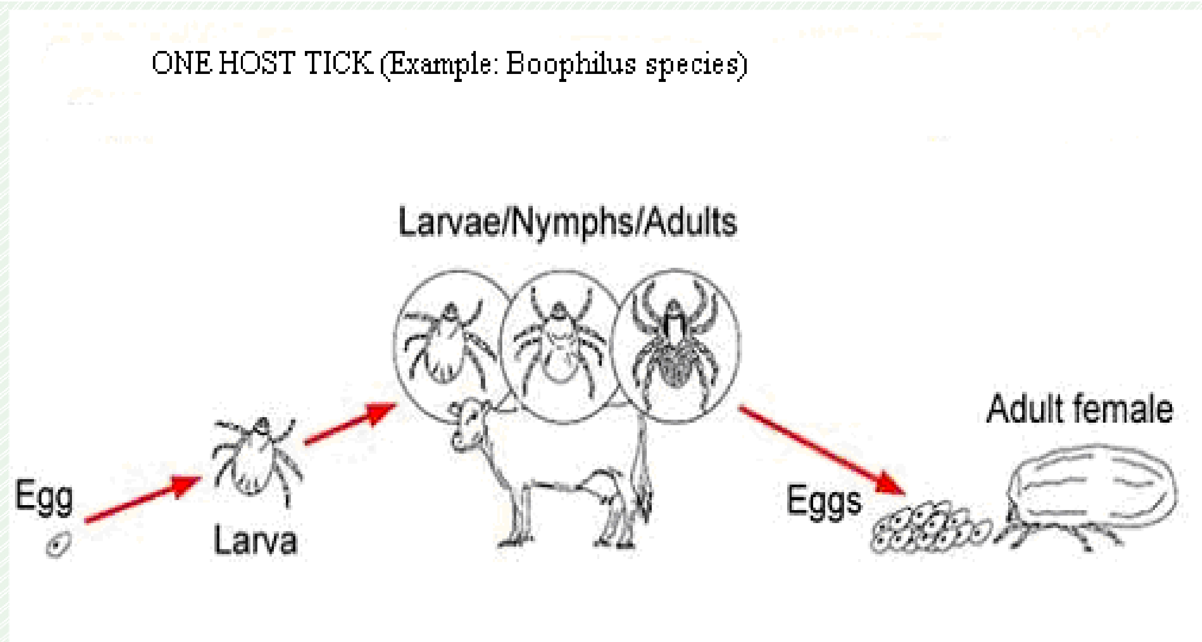


Plate 4. Distribution of *Boophilus* species in Ethiopia

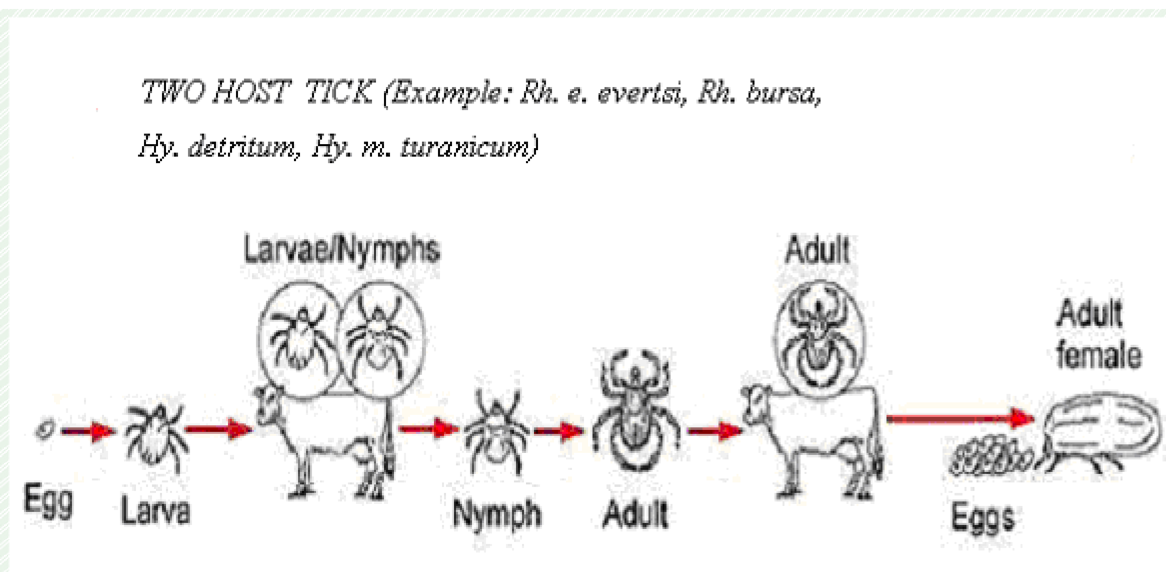
Annex 11. Pictorial representation of ticks' life cycle type.

Plate 1. Pictorial representation of one-host ticks life cycle.



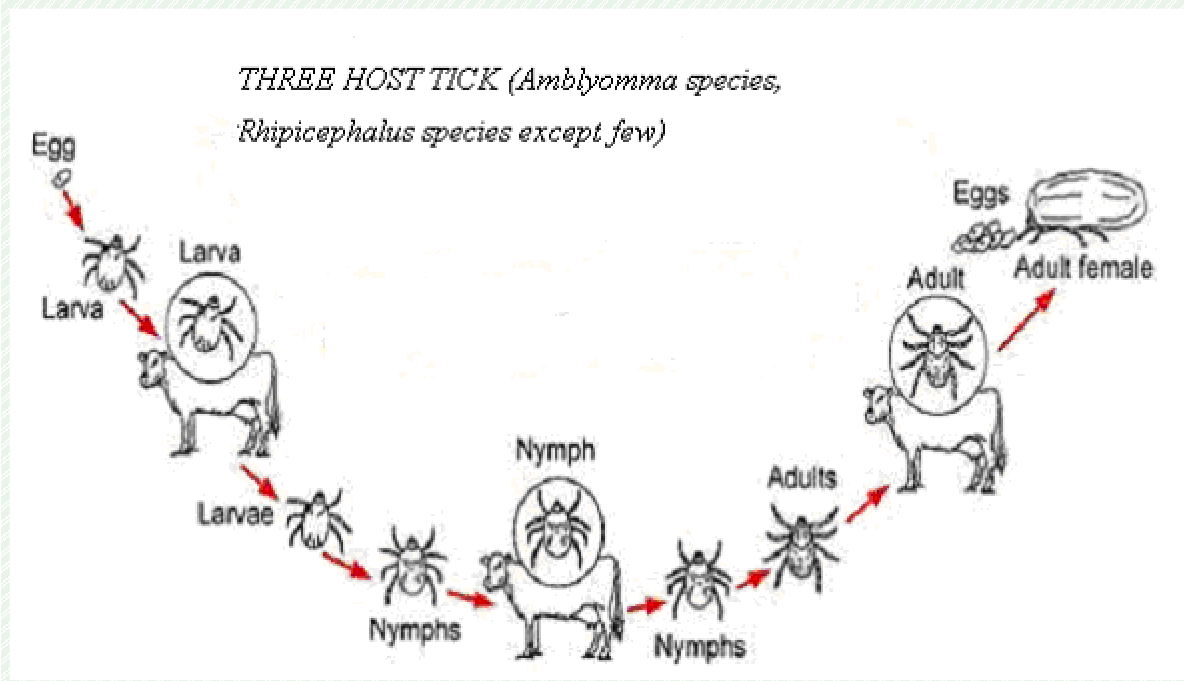
Source: Animal Health and Production Compendium (CABI Publishing, 2003)

Plate 2. Pictorial representation of two-host ticks life cycle.



Source: Animal Health and Production Compendium (CABI Publishing, 2003).

Plate 3. Pictorial representation of three-host ticks life cycle.



Source: Animal Health and Production Compendium (CABI Publishing, 2003).

9. CURRICULUM VITAE

1. PERSONAL DATA

Full name- Dr. Desie Sheferaw Mereba

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Occupation- Animal and Fisheries Resource Development Department Head, MoA, Soddo.

2. EDUCATION

I. MSc in Tropical Veterinary Epidemiology and Economics from Addis Ababa University Faculty of Veterinary Medicine, 2003 – 2005.

II. DVM from Addis Ababa University Faculty of Veterinary Medicine, 1987 - 1992.

III. Secondary school- Gedo secondary school, 1983 – 1986.

IV. Junior secondary and elementary school- Gedo Junior and Elementary school, 1975 – 1982.

3. WORK EXPERIENCE

- Animal and Fisheries Resource Development Department Head, 2003 – 2005
- Representative Office Head of MoA, Soddo Zuria District, 2002.
- Animal Health Team Leader, Soddo Zuria District, 2001 – 2002.
- Department Head of Animal Health Team, Damot Gale District, 1997 – 2000.
- Trainer of animal Health Technicians at Soddo Agricultural Training Centre, 1998/99.
- Animal and Fisheries Resource Development Team Leader.

4. RESEARCH PAPERS

- Cattle tick dynamics in different agro-ecological zones of Wolayta, Southern Ethiopia. MSc thesis, Addis Ababa University Faculty of Veterinary Medicine, 2005.
- Economic significance of Bovine Hydatidosis and Fascioliasis at Asela Abattoir DVM thesis, Addis Ababa University Faculty of Veterinary Medicine, 1992.

5. LANGUAGE

Good skill of writing and speaking: - English, Oromigna, Amharic and Wolaytigna

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10. SIGNED DECARATION SHEET

I the under signed, declare that the thesis is my original work and has not been presented for a degree in any university.

Name Desie Sheferaw Mereba

Signature ____________________

Date of submission ____________________

This thesis has been submitted for examination with my approval as University Advisor

Prof. Getachew Abebe ____________________________